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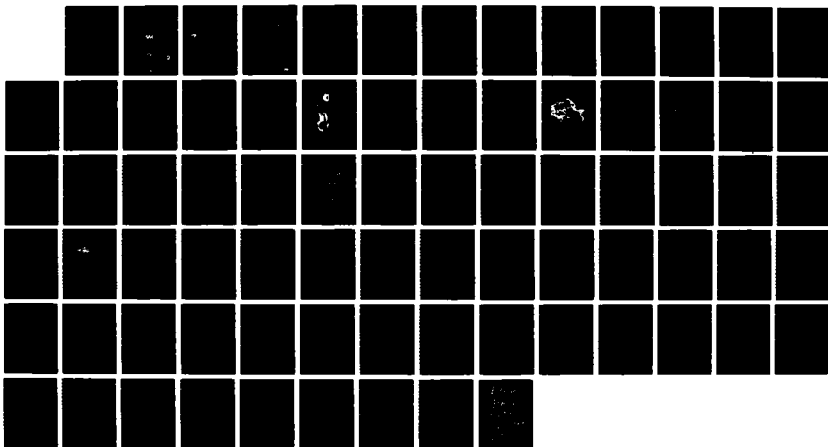
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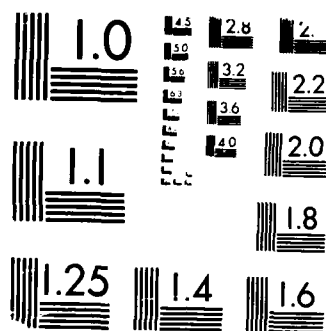
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IDENTIFICATION AND ACOUSTIC
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IDENTIFICATION AND ACOUSTIC
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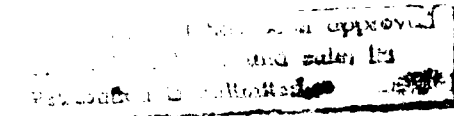
Prepared by:

A.I. Eller
L. Haines

Prepared for:

Naval Ocean Research and Development Activity

Contract No. N00014-86-D-0137
Delivery Order 002



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Section 1

INTRODUCTION

The presence of seamounts introduces a discrimination problem between acoustic returns from these geological features and from targets. The returns from seamounts can be quite large and can extend over long periods of time.

A process has been developed which will efficiently extract, identify and acoustically characterize seamounts. This process extracts seamounts from an area of ocean and estimates their location, height, base area and acoustic target strength.

These algorithms eventually will be included in the NOP Baseline model. Separate treatment of seamounts is necessary because the Baseline model, in its use of equally spaced radials about source and receiver for computing TL and reverberation, is likely to miss individual seamounts that lie between the radials.

This report describes seamount statistics, origins and summarizes bathymetric processing approaches used to extract them. The performance of the extraction software is evaluated by comparing a digitally derived database to a manually derived one. Seamount reverberation papers and seamount size statistics are presented along with a first order approximation of seamount target strengths.

Section 2

OVERVIEW OF THE SEAMOUNT PROJECT

The seamount project has developed several techniques for analyzing digital bathymetric data. To test these techniques an area in the Northeast Atlantic was selected that had two well documented seamounts. An area was retrieved over these two features from a $1/6^\circ$ data base (DBDB6). Gradient statistics were calculated for the area and are presented in grid (Figure 2-1) and histogram (Figure 2-2) form. The surface was modeled as a series of interconnected triangular plates. The vertices of these plates are coincident with the bathymetric data points. This modeling technique highlighted areas of steep slope which indicate seamounts or other rapid elevation changes.

Further development allowed the calculation of sea floor slope as viewed from a user defined look direction. The test area was analyzed from incremental azimuth angles so the slope characteristics of the seamounts could be evaluated. The seamounts exhibited slopes which were dependent on the look direction. Slope is important for estimating seamount returns because scattering intensity is dependent on angle. Two azimuth angles are presented in grid form in Figures 2-3 and 2-4. The areas of negative slope are in the shadows and would not be insonified from that particular look direction.

The work above demonstrated the sensitivity of sea floor slope on look direction as well as documented the slope patterns characteristic of seamounts.

The project emphasis shifted from the triangular plate modeling of the bathymetry to one that would enable the

Bathymetric Analysis

North-East Atlantic

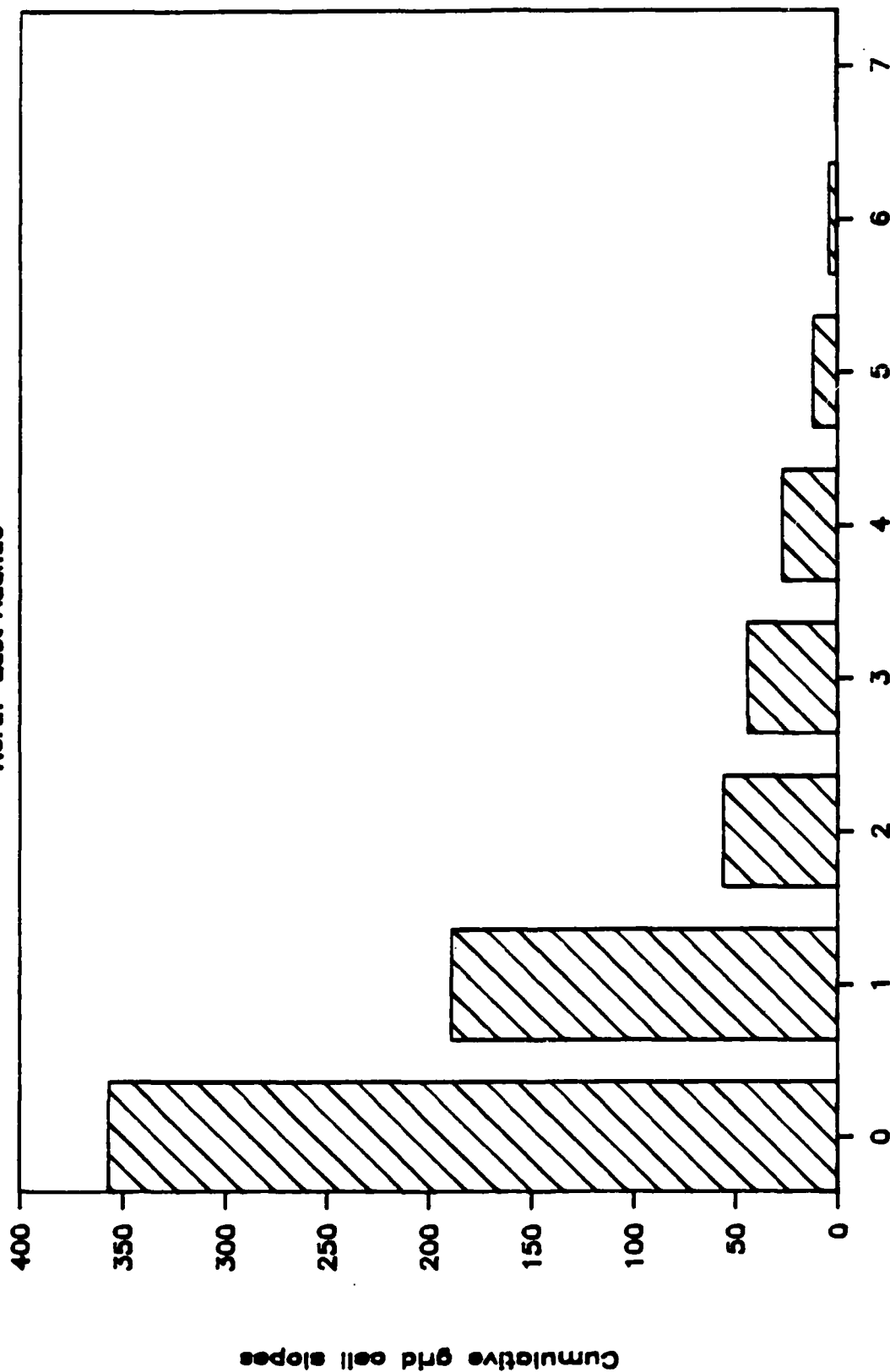


Figure 2-2. Grid Cell Gradient Histogram
North-East Atlantic

[illegible]

**Figure 2-3. Bathymetric Slope Grid Plot Azimuth South
Northeast Atlantic**

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.	.	.	.	+1	-4	-2	-1	-1	-1	-1	-1	.
.	.	.	+1	-4	-2	-1	-1	-1	-1	-1	.
.	-1	-6	-2	-1	-1	.	-1	.
.	-1	-6	-2	-1	-1	.	-1	.
.	-1	-2	-5	-1	-1	-1	.	.
+1	+1	.	.	+1	-1	-2	-5	-1	-1	-1	.	.
.	.	.	+1	+1	-1	-1	-3	-4	-1	-1	-1
+1	.	+1	+1	-1	-1	-3	-4	-1	-1	-1
.	.	+1
+1	.	+1	-2	-3	-3	-2	-1	.	.
.	.	+1	-2	-3	-3	-2	-1	.	.
+1	.	+1	-2	-3	-3	-2	-1	.	.
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+1	+1	-3	-4	.	+1	+3	+4	-1	-1	-3	-3	-2	-1	.
.	.	+1	-3	-3	-1	+1	+2	+6	-1	.	-1	-2	-3	-3	-2
.	.	+1	-3	-3	-1	+1	+2	+6	.	-1	-1	-1	-2	-3	-3	-2	.
.	.	.	-1	-4	-1	+1	+5	+1	-1	-1	-2	-4	-3	-1	.
.	.	+1	.	+1	-1	.	-1	-5	-5	-1	.
+1	.	+1	-1	.	-1	-5	-5	-1	.
.	.	+1	-1	-1	-1	-1	-2	-5	-2
+1	-1	-1	-1	-1	-2	-5	-2
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.	-1	-1	-1	-1	-1	-4	-2
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.	-1	-1	-1	-1	-1	-4	-2
.	-1	-1	-1	-1	-1	-4	-2
.	-1	-1	-1	-1	-1	-4	-2
.	-1	-1	-1	-1	-1	-4	-2

**Figure 2-4. Bathymetric Slope Grid Plot Azimuth East
Northeast Atlantic**

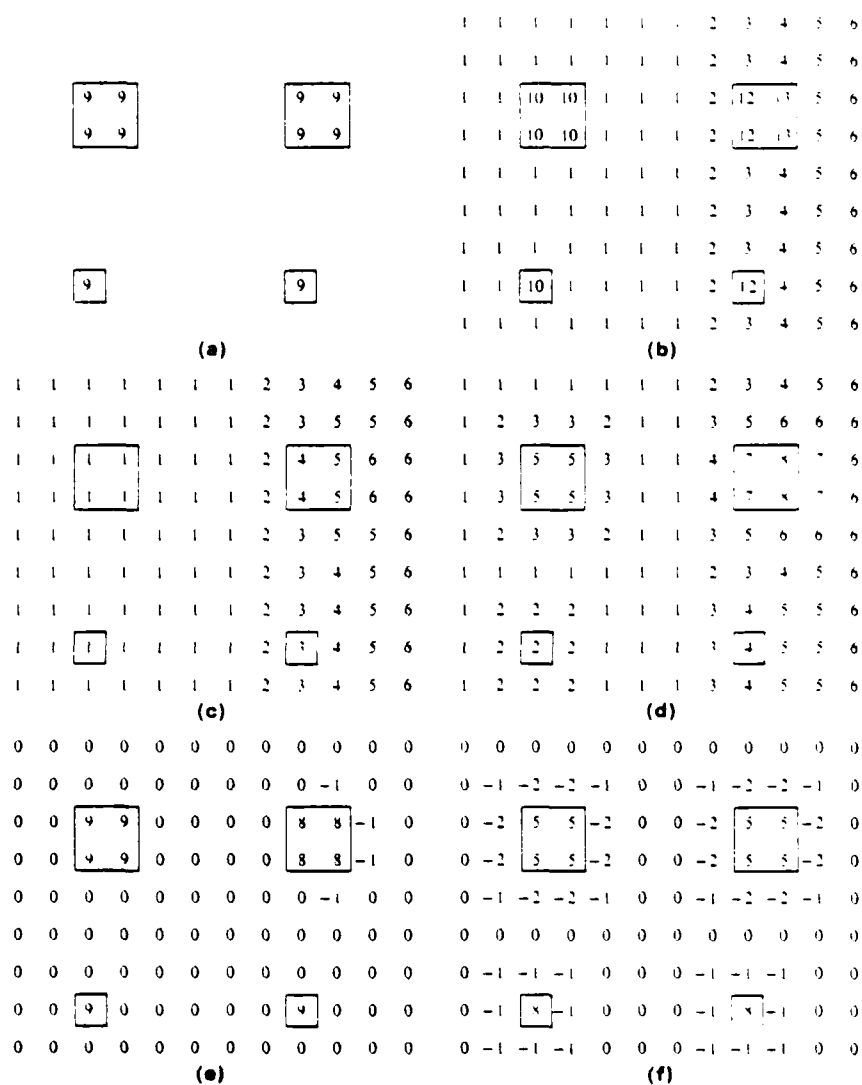
identification of seamounts within a grid. The objective was to create a seamount data base with their locations and associated shape statistics. This data base would allow the selection and acoustic modeling of seamounts along a user defined radial.

A processing sequence was initiated which would extract the seamounts from a bathymetric grid. This process involved filtering, subtracting, and thresholding gridded data. A processing sequence commonly used in picture processing to remove objects from a smoothly varying background was used to extract seamounts. This processing sequence involves the removal of the long period elevation changes over the bathymetric grid. Filtering is used to estimate these elevation variations.

A median and average filtering extraction was performed on bathymetric data. This sequence is illustrated in Figure 2-5. The median filter was most successful at estimating the smoothly varying sea floor elevations. The median estimate is subtracted from the input grid, this results in an elevation grid which is referenced from the sea floor. This elevation grid contains both positive and negative values. Elevation values were removed from the grid if their elevations were below 400 meters. The resulting grid contained large positive sea floor elevations which are typical of seamounts.

The location of these seamounts were determined by calculating the center point (latitude and longitude) of these positive areas. A contouring algorithm was used to determine the outer grid cells surrounding the seamount.

The base area of the seamount was calculated by summing the areas of the cells around its perimeter and



Object extraction. (a) Original objects; (b) filter input grid, consisting of objects with added background; (c) 3 x 3 median filtering of the input grid; (d) 3 x 3 moving average filtering of the input grid; (e) subtraction of (c) from the input grid; (f) subtraction of (d) from the input grid

Figure 2-5. Filtering Sequence of Gridded Data

interior. Maximum height, vertical cross sectional area and target strength statistics were computed. These statistics were written to a file for all seamounts within the grid. A pictorial diagram illustrates the processing sequence required to create a database of seamount statistics (Figure 2-6).

A preliminary seamount data base has been assembled over the NOP Test Area. This area covers the area between latitudes (29-42 degrees) and longitudes (60-76 degrees). The extraction process has identified 39 seamounts within this area and their associated statistics. Statistics for these seamounts have been sorted by seamount latitude and placed into a data base.

Software has been written which determines what seamounts have been intercepted along a user defined radial. The user supplies the source position, track bearing, maximum range, and beam width. Statistics are output for the seamounts that have been intercepted by the beam.

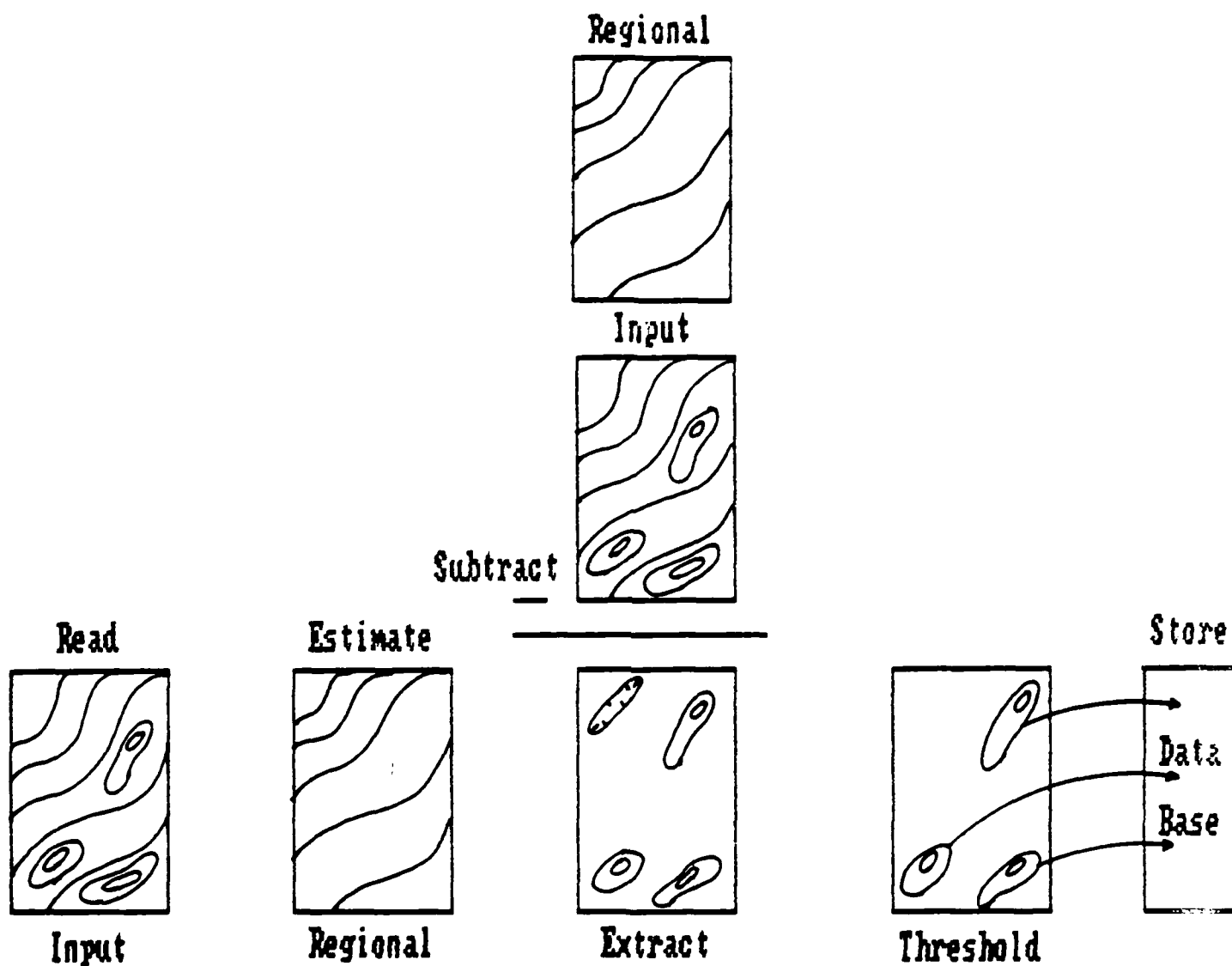


Figure 2-6. Pictorial Diagram of Seamount Extraction Sequence

Section 3

SEAMOUNT DEFINITION, ORIGINS AND ACOUSTIC IMPORTANCE

A seamount was defined by Menard [15] as being "a more or less isolated elevation of the sea floor with a circular or elliptical plan, at least 1 km of relief, comparatively steep slopes, and a relatively small summit area." This definition is still in use except the 1 km height cut-off has been reduced to approximately 400 meters.

A seamount forms as a volcanic cone created by the extrusion of magma from below the earth's crust (Figure 3-1). Seamounts form in clusters, linear chains, and appear as isolated features. Their geographic distributions are non-uniform.

Bathymetric surveys indicate that seamounts form at or near the plate boundaries. The creation of a seamount requires a source of magma and a path or conduit to transport the magma. These conditions are most often met along these boundaries.

The size of seamounts depends upon the volume of magma available and the configuration of the magma conduits feeding the seamount. Size can also be influenced by the sediment thickness, stress patterns in the crust and several other factors. Combinations of the above parameters produce seamounts with heights ranging from several hundred to several thousand meters.

Seamounts are acoustically significant because they produce large returns which can mask targets of interest. These large returns are caused by a number of factors. Large

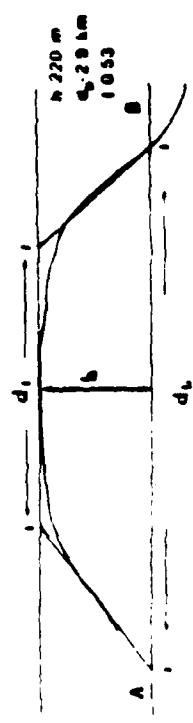
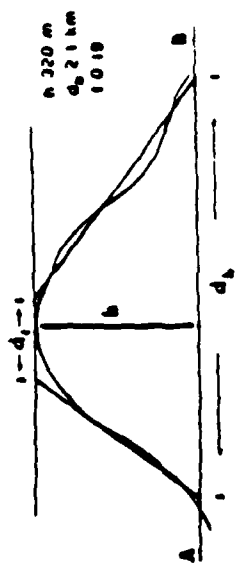


Figure 3-1. Seamount Profiles and Plan Views

seamounts tend to block portions of the acoustic channel scattering the incident energy. Typically the flank slopes of seamounts approach 18 degrees. These slopes increase the angle of incidence with the acoustic wavefront resulting in greater backscattering values.

Section 4

LITERATURE REVIEW

4.1 SEAMOUNT HEIGHT DISTRIBUTION IN THE PACIFIC OCEAN

The acoustic response of a seamount will be largely determined by its size. The seamount height is the most critical parameter in size determination.

Seamount heights can range from a few hundred meters to several thousand meters. The wide range of sizes that seamounts exhibit is an important factor in estimating their acoustic response. The size and shape of a seamount affects the probability that it will interact with an acoustic wavefront. An analysis of the size distributions of seamounts is important in estimating the probability of seamount returns within a given area of ocean.

Methods of Measuring Seamount Height

Seamount height statistics can be compiled using bathymetric charts, profiles and multi-beam swaths. These data acquisition tools record depths over portions of the sea floor. Each tool has certain limitations in the resolution of seamount size.

Charts provide an accurate means of estimating the number of seamounts which exceed 3000 meters. Smaller seamounts are under-represented on charts. Seamounts less than 600 meters are accurately measured by multi-beam swaths. The multi-beam swath has a small footprint which allows the complete imaging of seamounts which are less than 600 meters

tall. Wide-beam echo-sounding profiles can image seamounts between 600 and 3000 meters.

There are few areas where detailed height studies have been performed. Smith [18] compiled detailed height statistics for eight areas in the Pacific (Figure 4-1). Wide-beam profiles were chosen for this height analysis because they properly image seamounts over the widest range of heights.

Seamount shapes were also evaluated using 70 high resolution surveys. These surveys indicated that seamount shape could be described using three parameters: flank slope (e), height to radius ratio (E), and flatness (f). These shape indicators are illustrated in Figure 4-2. The 70 seamounts surveyed are scatterplotted in terms of their height and shape parameter (f) in Figure 4-3. Seamounts with large flatness values have larger summit radii than cone shaped seamounts where $f = 0$. The size of the summit determines the probability of recording their actual height (i.e., the larger the summit, the greater the probability of recording the actual height). Heights recorded for cone shaped seamounts are understated if the profile does not traverse the apex of the cone.

Profile height statistics are illustrated in histogram form for each of the eight areas (Figures 4-4 and 4-5). A cumulative distribution histogram was constructed for all eight areas which contained 5909 seamounts. This graph is illustrated in Figure 4-6. This cumulative distribution was approximated using both an exponential and power law distribution model.

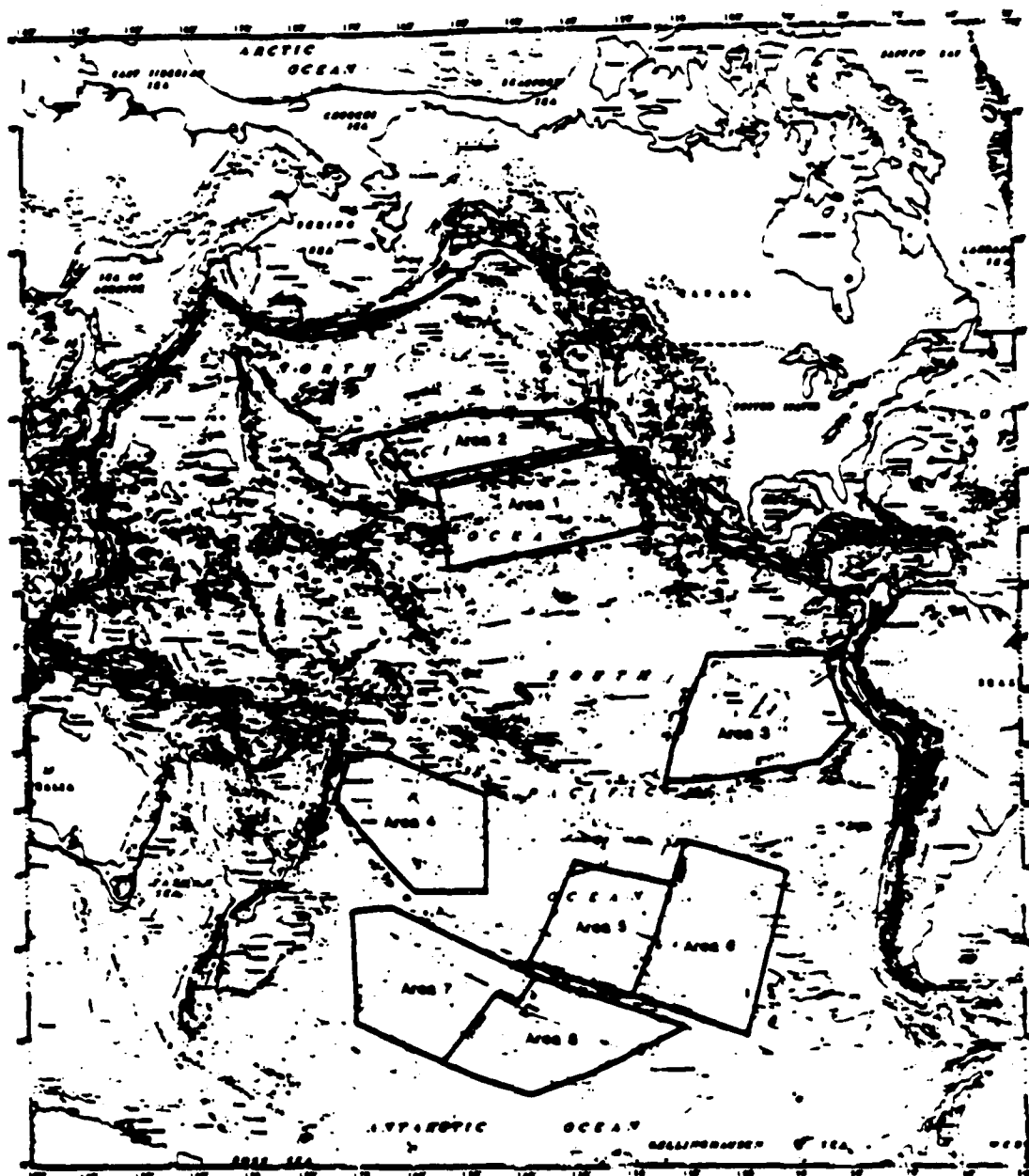
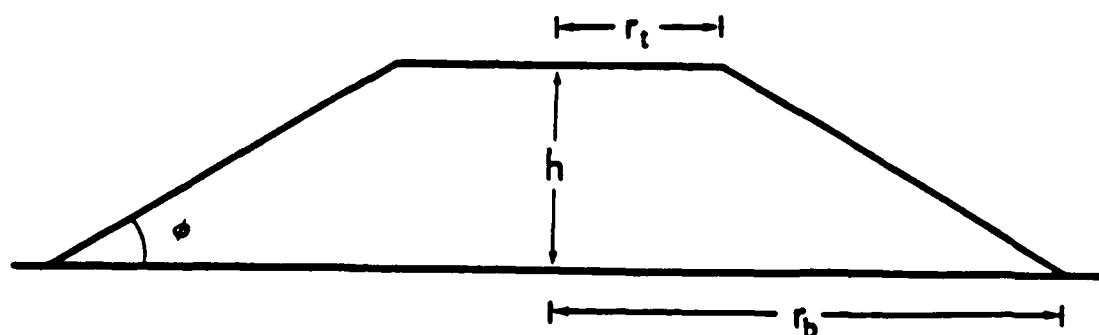


Figure 4-1. Location Map of Seamount Study Areas



$$f = r_t/r_b$$

$$e = \tan \phi$$

$$E = e(1-f)$$

Cross section of a flat-topped seamount with cylindrical symmetry. Size is described by the basal radius, r_b . The shape is described by the flatness, f , and the height-to-radius ratio, $E = \frac{h}{r_b} = e(1-f)$, where $e = \tan \phi$.

Figure 4-2. Shape Parameters for a Typical Seamount

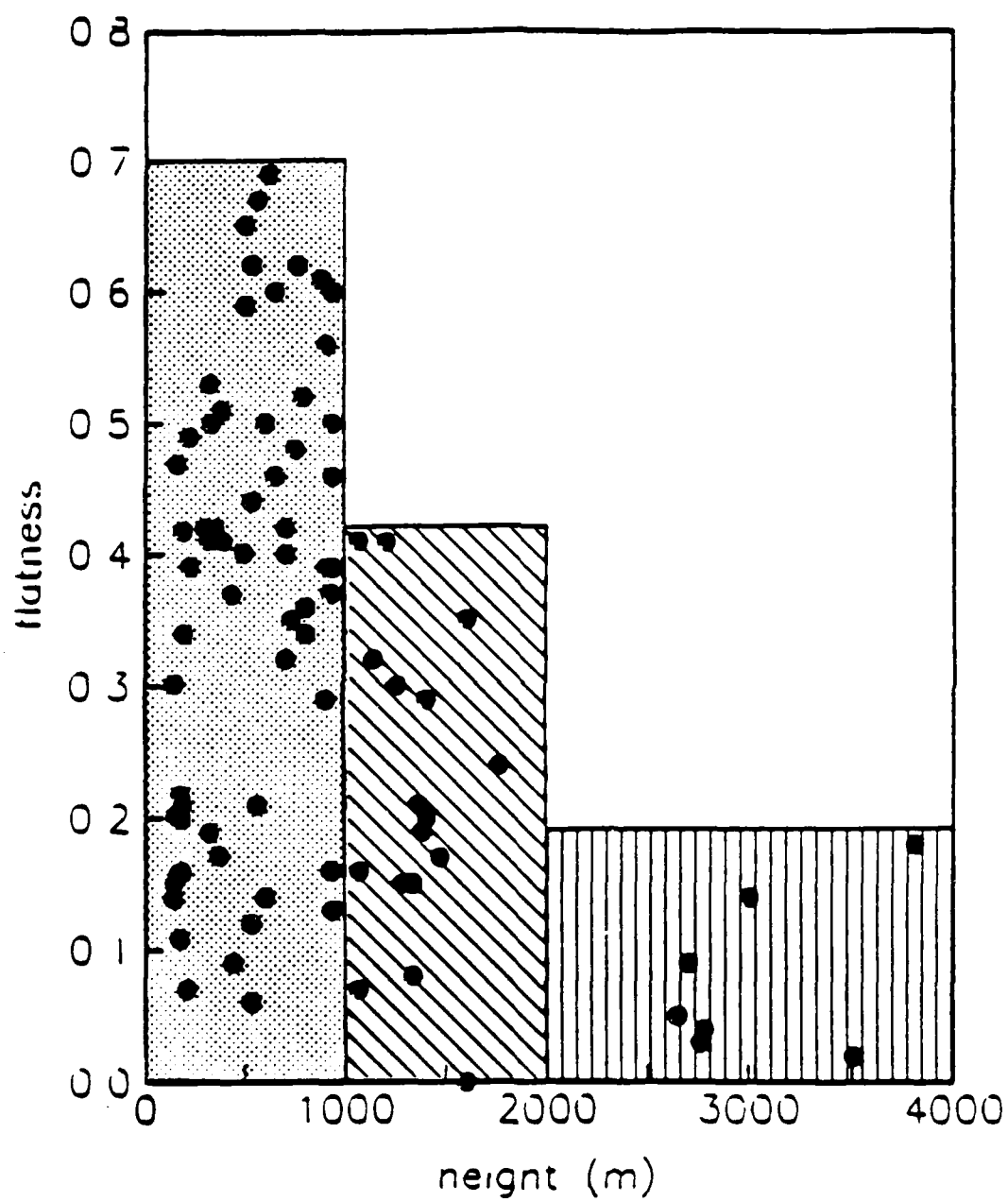
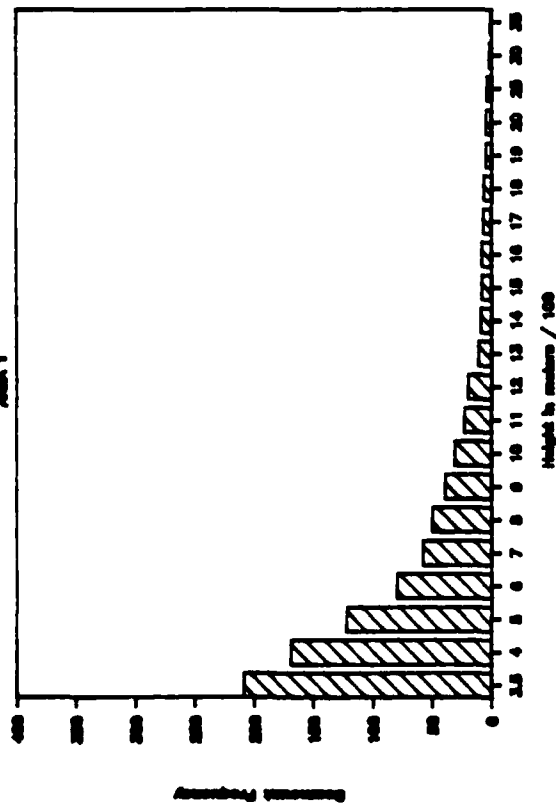


Figure 4-3. Scatter Plot of Seamount Height and Flatness

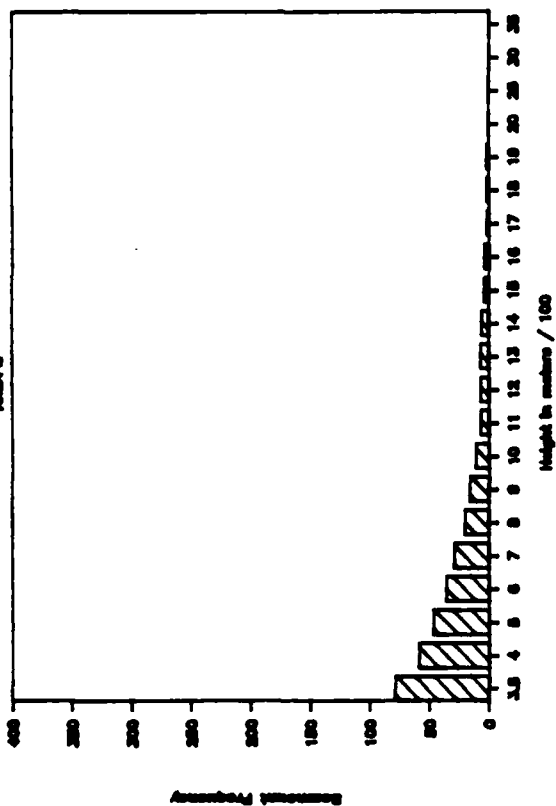
Seamount size analysis

AREA 1



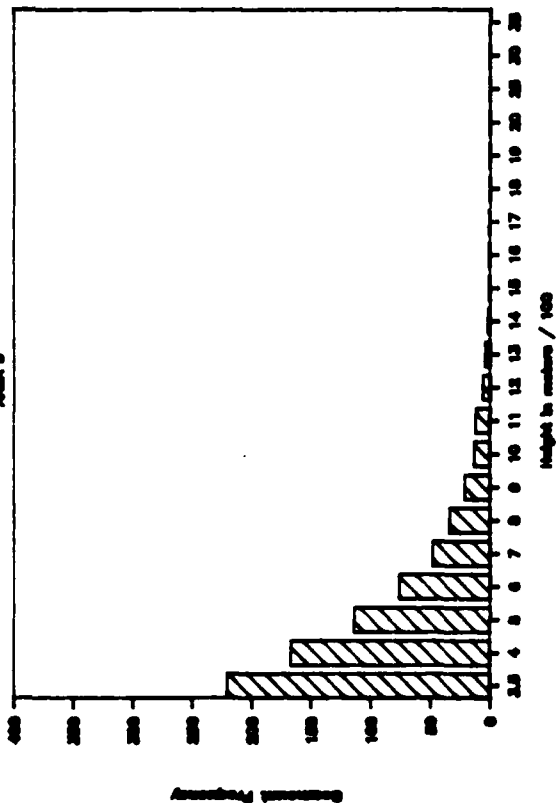
Seamount size analysis

AREA 2



Seamount size analysis

AREA 3



Seamount size analysis

AREA 4

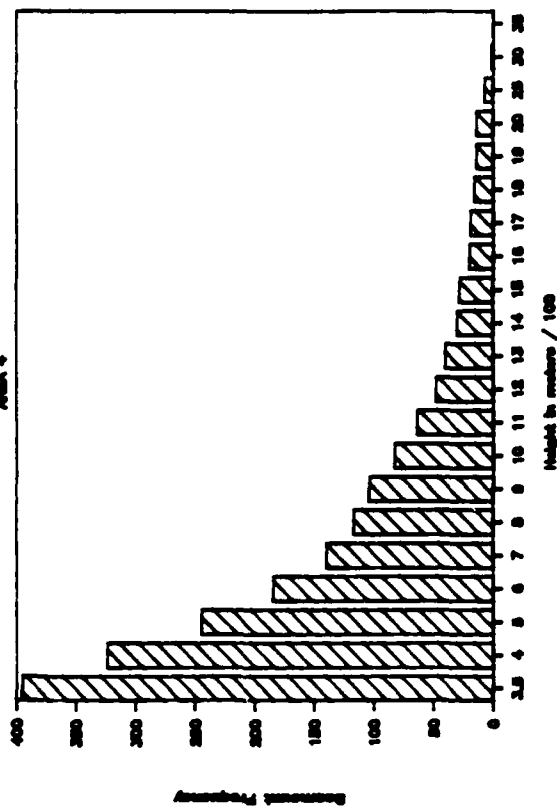
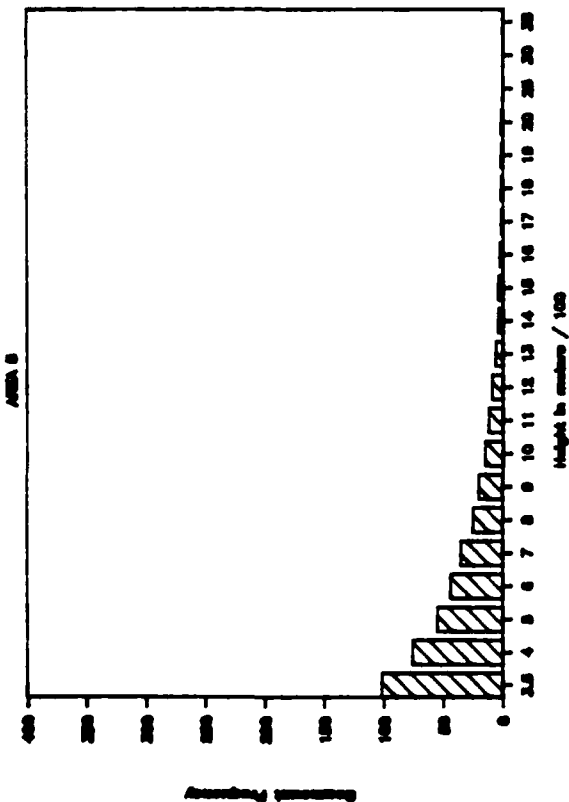
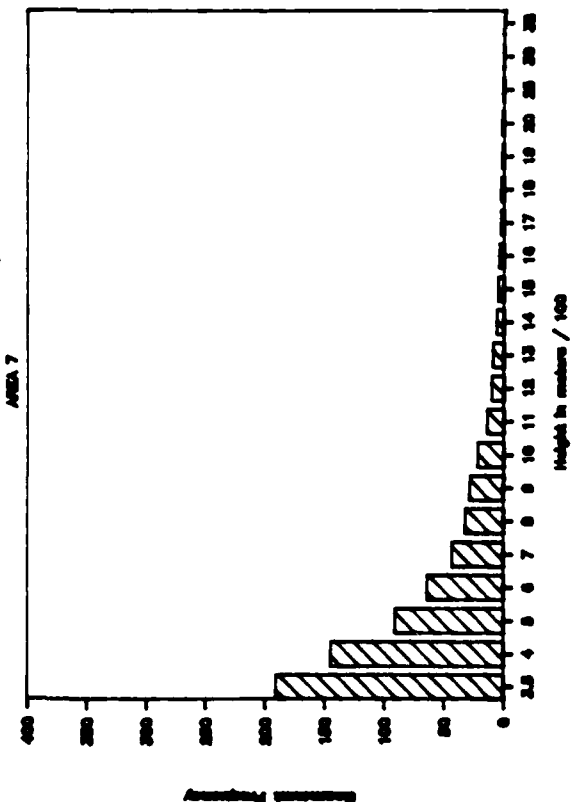


Figure 4-4. Seamount Height Histogram Areas 1-4

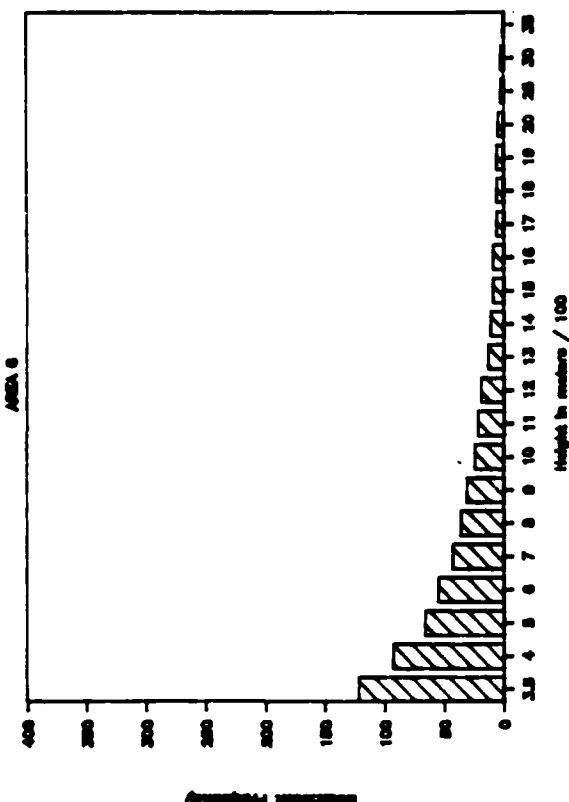
Seamount size analysis



Seamount size analysis



Seamount size analysis



Seamount size analysis

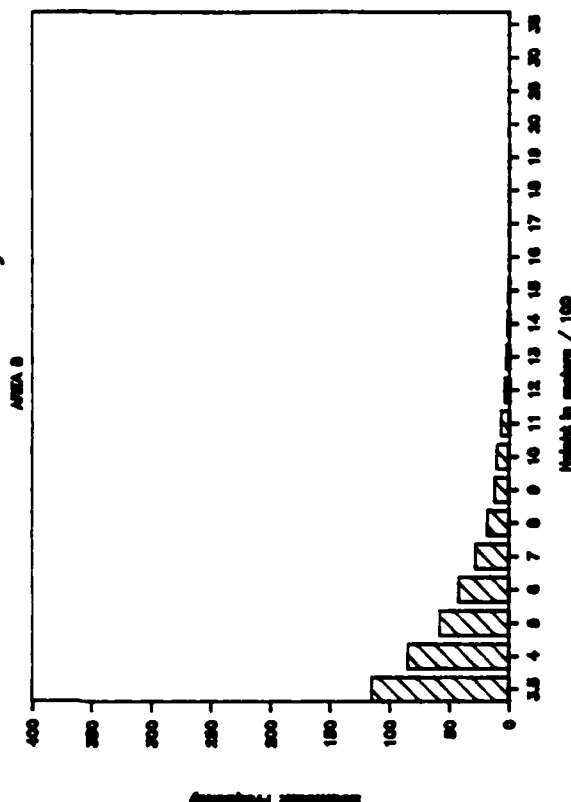


Figure 4-5. Seamount Height Histogram Areas 5-8

Seamount size analysis

ALL EIGHT AREAS

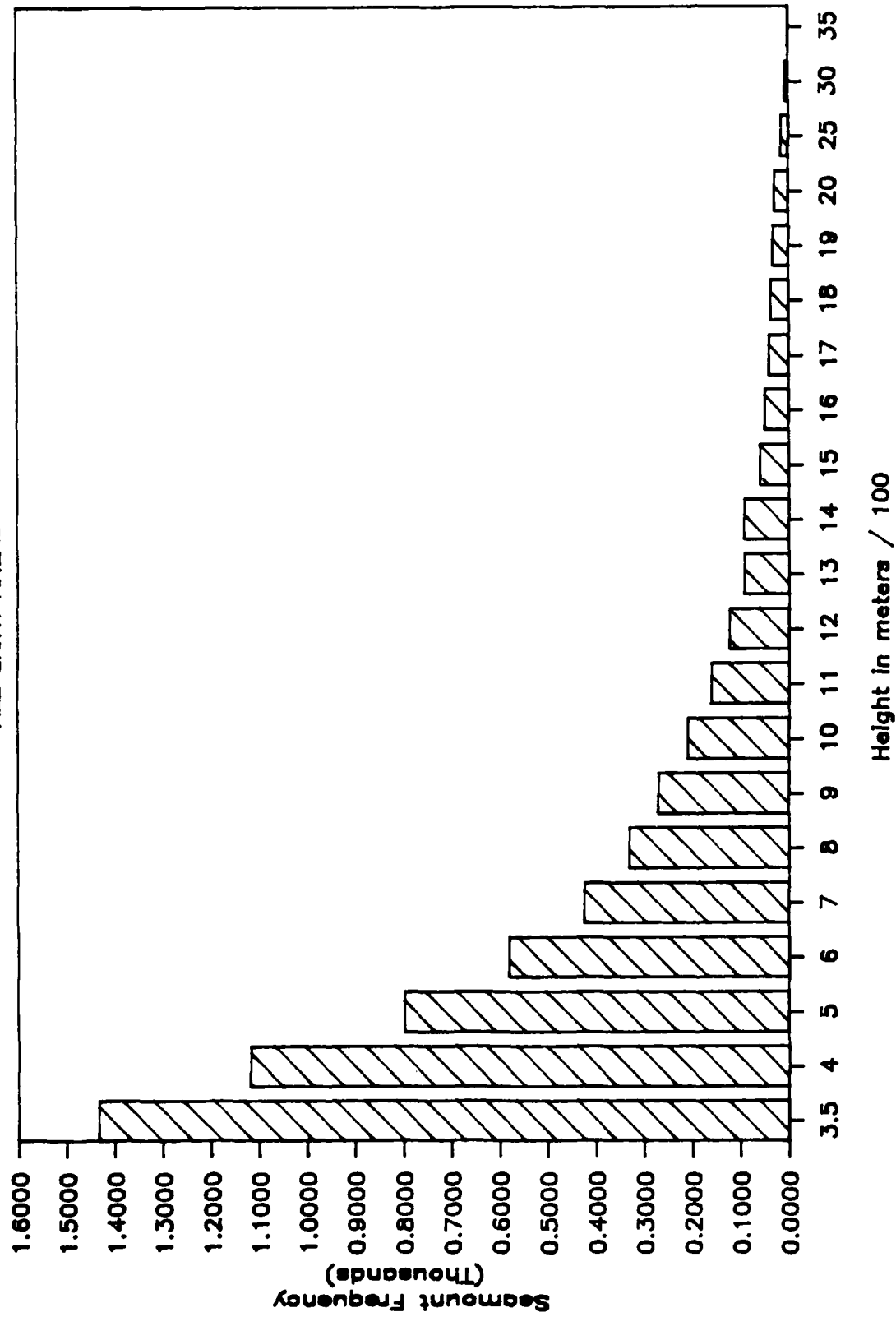


Figure 4-6. Cumulative Height Histogram

An exponential distribution can be expressed as

$$y = ae^{-bx}$$

where y is the number of seamounts, x is the height of the seamount, and a and b are coefficients of the distribution. In terms of the same variables a power law distribution is written as

$$y = ax^{-b}$$

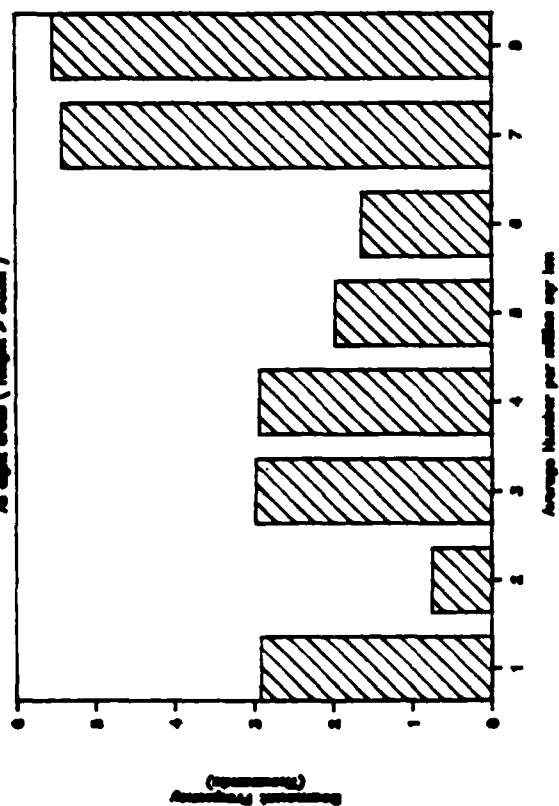
The exponential distribution satisfied the data over the largest range of heights and is the preferred model. The frequency versus height statistics are one-dimensional and are of limited utility when used to determine the probability of seamount reverberation within an area of ocean.

The seamount height profile analysis was extended into two dimensions so area distributions of seamounts could be estimated. The area density of seamounts is important when determining the reverberation levels for particular areas of ocean.

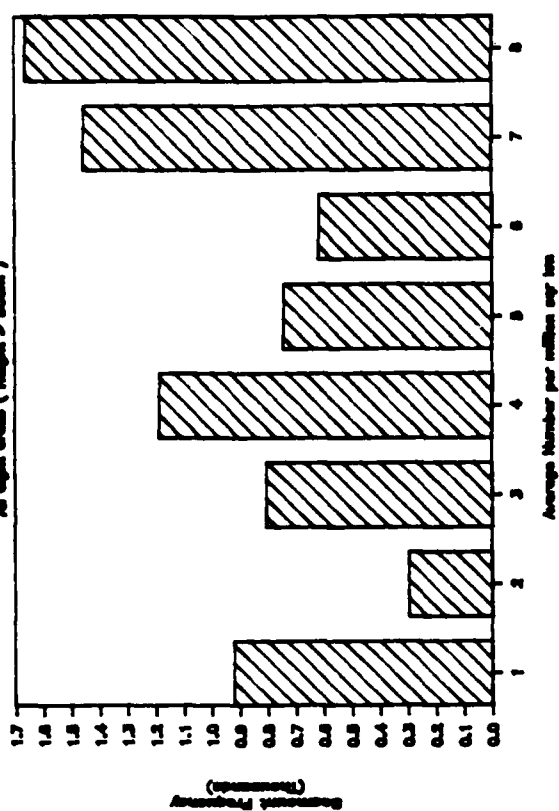
The density distributions were determined by assuming the profiles within the area were random tracks which recorded a representative sample of the seamounts. The percentage of the areas actually sampled varied from one to six percent of the total. Due to the small sampling area, it is possible that the actual seamount density is quite different.

Seamount densities for all eight areas are plotted in Figure 4-7 as cumulative histograms. These graphs illustrate the number of seamounts within each area that have heights exceeding 300, 500, 1000, and 2000 meters.

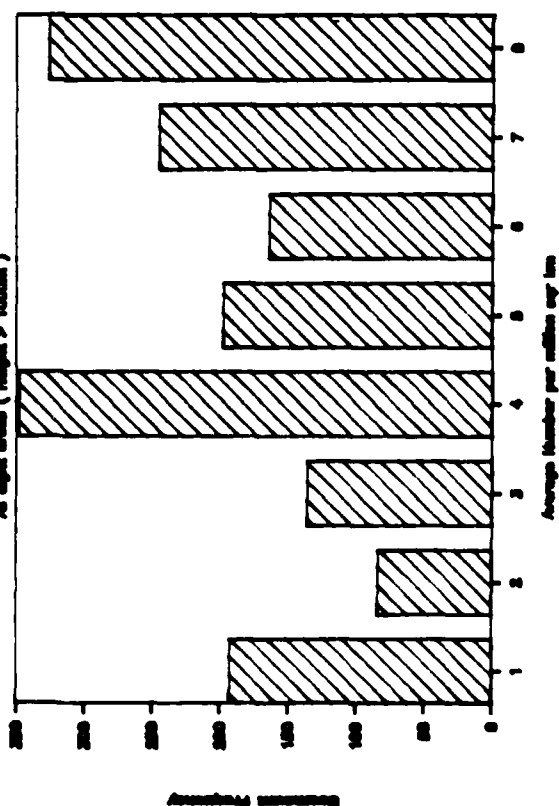
Spatial seamount density
All right areas (Height > 2000m)



Spatial seamount density
All right areas (Height > 2000m)



Spatial seamount density
All right areas (Height > 1000m)



Spatial seamount density
All right areas (Height > 2000m)

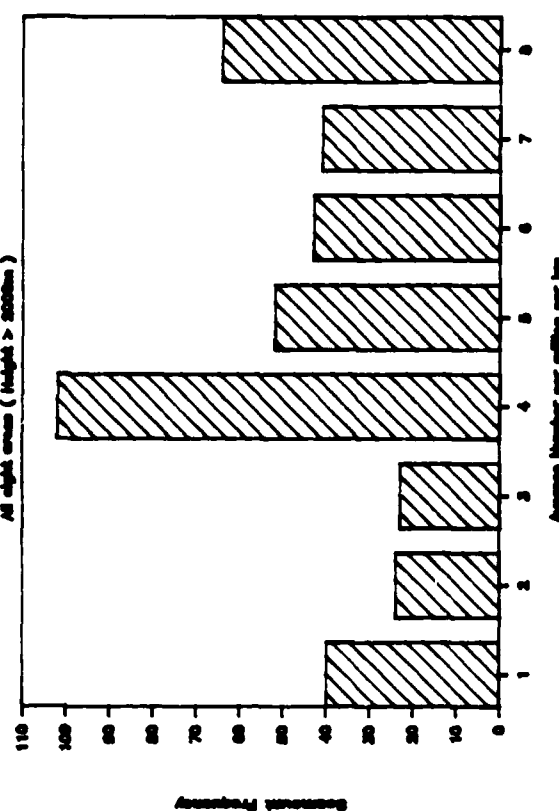


Figure 4-7. Area Density of Seamounts Histogram

4.2 ACOUSTIC RETURNS FROM SEAMOUNTS

Background Data

The following is a summary of literature relevant to the estimation of acoustic returns from seamounts. Scattering from seamounts is governed by (1) the scattering strength of the material that comprises the seamount, (2) the size and shape of the seamount, and (3) interception by the seamount of refracted paths that otherwise would not reach the bottom.

Measurements of acoustic scattering by seamounts are presented by Carlton and Crooks [1] (and later presented again by Fagot [10]) and by Erskine, Franchi, and Adams [7]. Of these, the most extensive measurements of backscatter strength are of Henderson Seamount [1]. Most of the measured Henderson scattering strengths range from -6 to -14 dB/yd² and were reported as being generally close to Urick's curves for rock and sand bottoms. These measurements were made at 2, 4 and 6 kHz and at grazing angles from about 20 to 80°, as shown in Figure 4-8. The values of scattering strength thus measured stand sharply in contrast to other reported values, which range from -30 to -50 dB, as presented in Figure 4-9, based on shallow water FASOR stations at 1500 Hz.

These data do not address the central issues of low frequency, small angle bistatic scattering. They do suggest, however, that the scattering contribution of a seamount may be describable in terms of its area and a large scattering strength value.

These values of scattering strength are not consistent logically with the familiar scattering coefficient -27

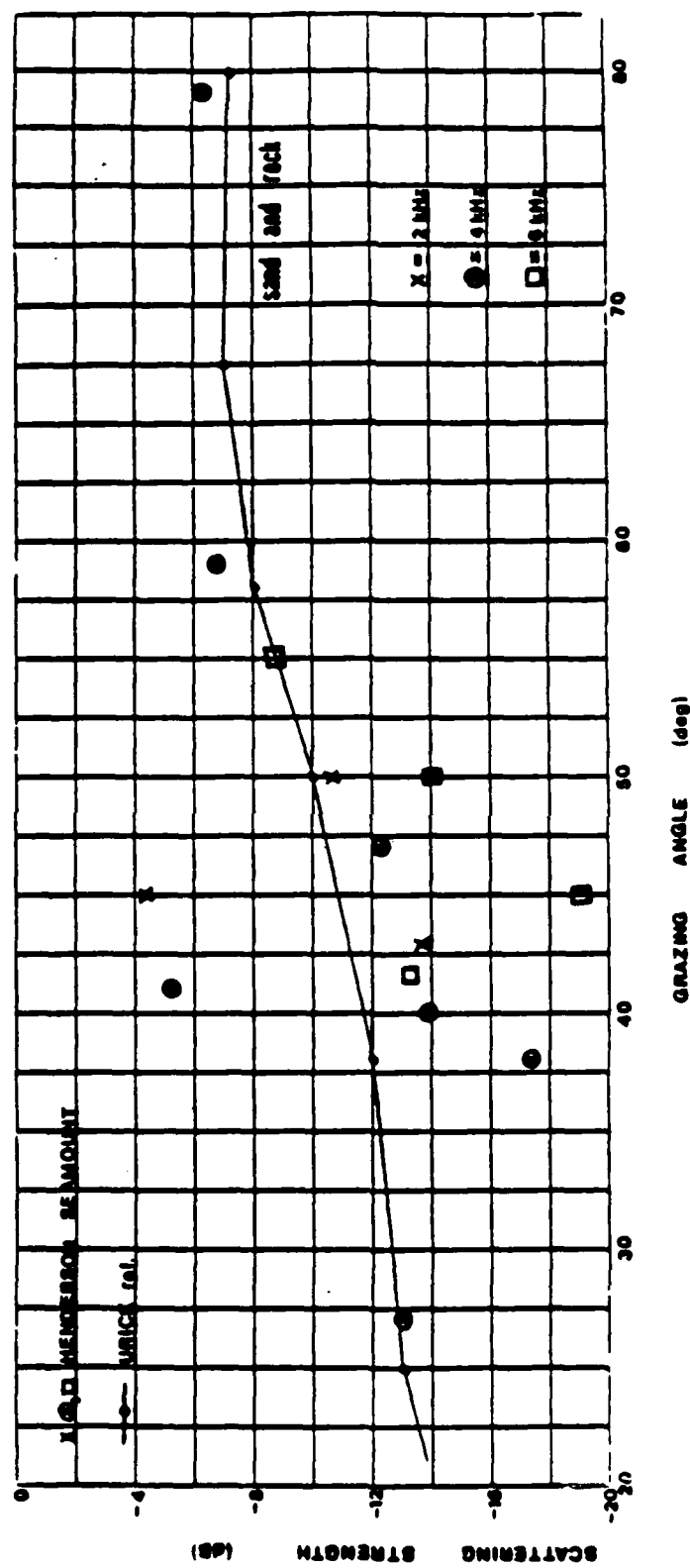


Figure 4-8. Scattering Strength versus Grazing Angle -- 2, 4 and 6 kHz

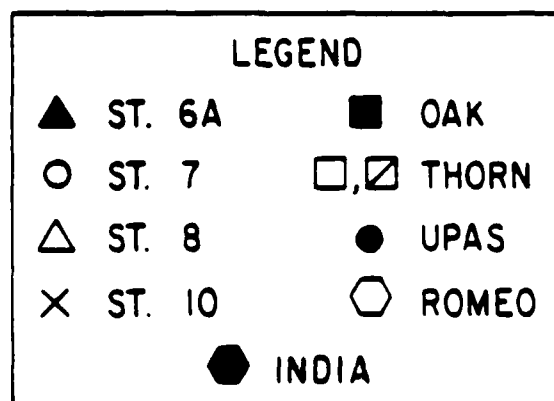
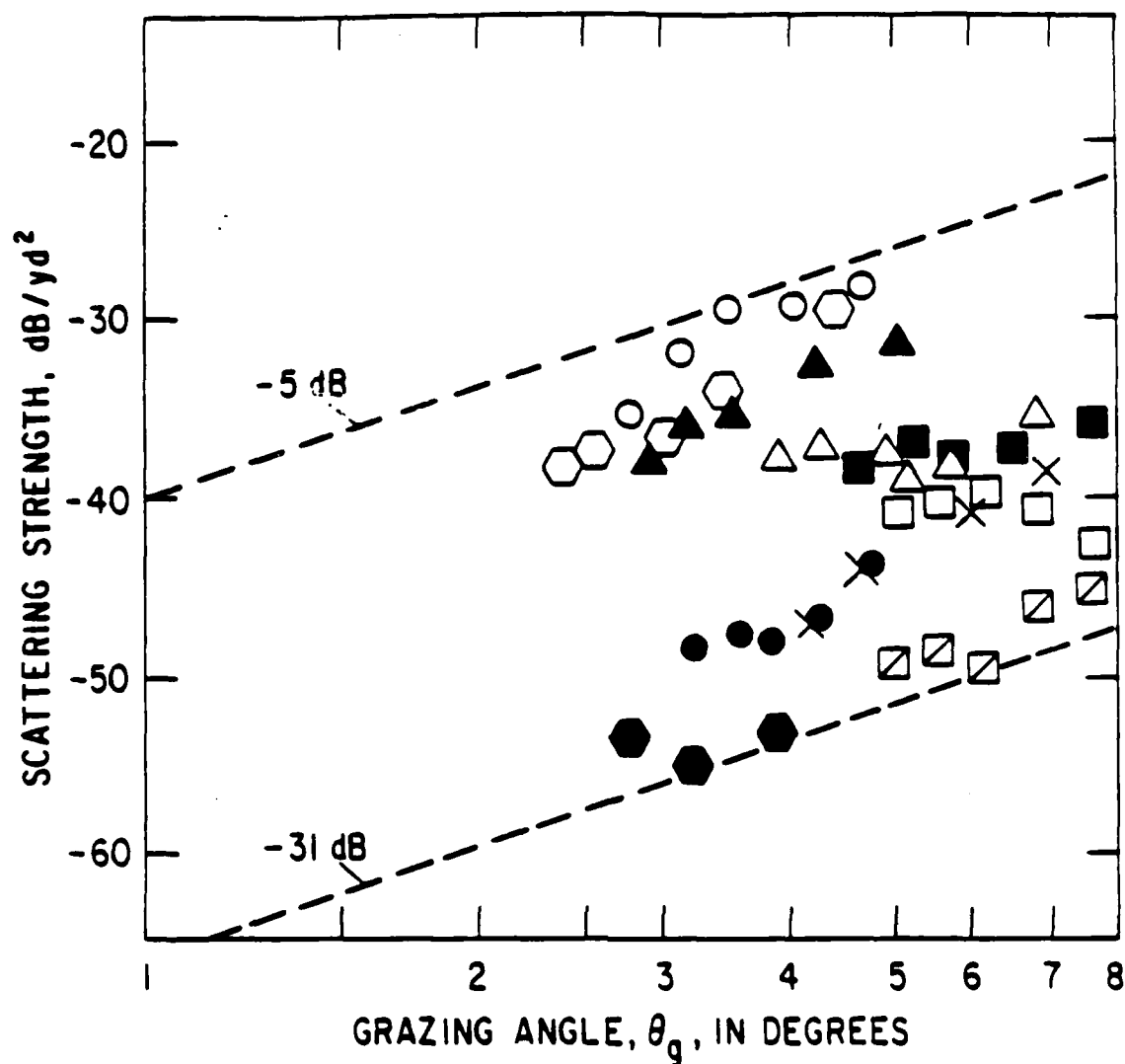


Figure 4-9. Scattering Strength as a Function of Grazing Angle

dB/yd² attributed to measurements of ocean bottom scattering by Mackenzie [14]. The Mackenzie value is intended to be used as part of Lambert's Law, which would multiply the coefficient (e.g., -27) by the square of the sine of the grazing angle. For representative grazing angles of 5°, the resulting scattering strength would be about 20 dB lower, in the range from -45 to -50 dB. It should be realized here that the Mackenzie value was extracted from data at grazing angles above about 30°.

Fagot [10], in a later application of the results of Carlton and Crooks, used a straight line fit to give the following linear angle dependence of the scattering strength SS:

$$SS \text{ (dB/m}^2\text{)} = -16 + \frac{\theta - 20^\circ}{6}$$

where θ is the grazing angle in degrees of the acoustic signal at the bottom. This relation is shown in Figure 4-10.

NRL studies [7] have addressed the detection of seamounts at long range. Figure 4-11 shows examples of scattering strengths backed out of the measured reverberation. The technique differs from the Henderson Seamount results primarily in that these measurements are made at long range and no attempt was made to measure the corresponding grazing angle. A criticism of the work might be that a highly smoothed TL curve is used for the estimation of scattering strength. Accordingly, the results do not reflect the fact that TL to the bottom would differ from TL near the peak of a seamount, which might account for the abnormally low scattering strength (about -70 dB) in the region before the seamount. Nevertheless, the NRL results appear to substantiate the relatively high values of about -20 dB on the seamount.

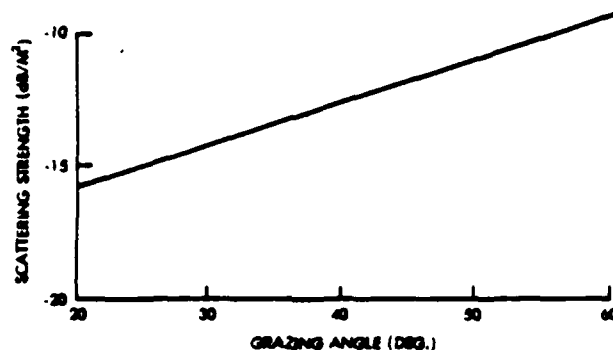


Figure 4-10. Bottom Backscattering Strength for the Henderson Seamount Measured with the TOPS System

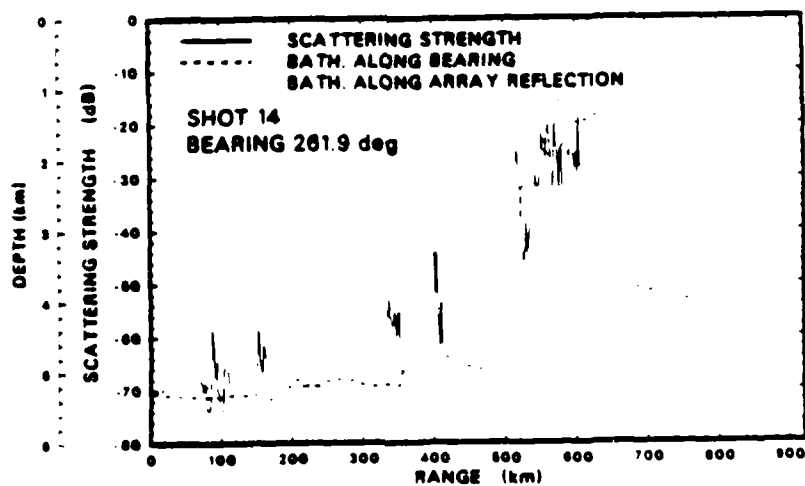


Figure 4-11. "Scattering strength measure" (see text) vs. range for a selected radial. Also shown is SYNBAPS bathymetry for primary radial (dashed) and conjugate radial (dotted).

None of these references cites a value of acoustic target strength for a seamount, but such values may be estimated by using the relation

$$TS = SS + 10 \log (\text{Area})$$

where the area is approximated by the horizontal projection. For a moderately sized seamount, 5 nmi in diameter, this area is about 20 nmi², and the resulting target strength for a scattering strength of -20 dB, would be

$$\begin{aligned} TS &= -20 + 10 \log 20 + 66 \\ &= 59 \text{ dB} \end{aligned}$$

(The additional 66 dB represents the conversion from nmi to yd.)

An analytic or modeling approach to seamount scattering was devised by Goertner [13], who provides the following representation of a seamount: The straight line boundaries of the seamount are defined by 3 to 10 vertices, connected by straight line segments, defined usually at the 1000-fm contours. Each bounding segment is characterized by a slope at the midpoint derived from the perpendicular separation between 500-fm contour spacing. Finally, to each bounding segment, a symmetrical trapezoidal face is identified, with a base angle equal to the average slope. The target strength for an acoustic signal perpendicular to the bounding segment is estimated by

$$\begin{aligned} TS &= 10 \log (\text{Area}) \\ &\quad + 10 \log (\beta/90^\circ) \end{aligned}$$

where the Area is taken as the vertical projection of the trapezoidal area, and β is the average face slope in degrees. This term is a correction for oblique incidence.

Appendix B lists the segment lengths, the vertical projection areas of each trapezoidal face, the associated target strength, the average slope angle, and the location of several seamounts in the NOP test area.

Section 5

SEAMOUNT TARGET STRENGTH

This section defines an approach for obtaining seamount target strength and associated parameters from a digitized bathymetric data base and for utilizing these data to estimate the acoustic response, consistent with the constraints and procedures of the NOP baseline model. A primary constraint is the use of preselected uniformly spaced radials for TL calculations, which preclude the selection of TL calculations along paths that intersect specific seamounts. The NOP requirement to conduct wide area acoustic performance assessments in relatively short time with modest computer resources also imposes a constraint on how the problem must be approached.

The problem is divided into two steps: 1) identification of seamounts, from a seamount data base, that lie within a specified span of bearings from the receiver; 2) characterization of the response of the selected seamounts.

Seamount target strengths are estimated from gridded digital bathymetric data. The grid cells coincident with a seamount are determined by a contouring algorithm. The vertical projection of the grid cell area is assumed proportional to the target strength. The seamount target strength is calculated by summing the vertical (cross sectional) area contributions of all grid cells within the seamount.

The target strength relationship used by NSW (Goertner), is based upon the cross section of intercepted seamount area. This method has been modified so that the

target strength can be estimated automatically from the digital bathymetric data. Target strength is related to the cross sectional area and slope of a seamount by the following equation:

$$TS = 10 \log (AREA) + 10 \log (\beta/90)$$

where the AREA is the cross sectional area in square meters and β is the seamount slope angle in degrees. A constant seamount slope angle of 15 degrees was used for the second term.

An estimate of the cross sectional area of each grid cell is determined by evaluating four neighboring grid cells. Four equal area triangles are constructed using the center grid cell as a local origin. The Grid cells and the four triangular areas are illustrated in Figure 5-1.

The cross sectional areas are calculated for the four triangles and averaged to get an estimate of the cross sectional area of the center cell. The four inter-connected triangular areas (ITAs) have a common vertex at the center cell which is used as a local vector origin. The vectors, grid cells and grid cell center points are shown in Figure 5-1 and will be used to illustrate the cross sectional area calculations.

Each ITA is considered a plane formed by two vectors (\vec{A} and \vec{B}). The orientation of each ITA can be quantified by computing a normal vector to its surface. The cross-product of \vec{A} and \vec{B} yields a normal vector which has a magnitude equal to twice the triangular area. The vector expressions for determining the attitude of the ITA are as follows:

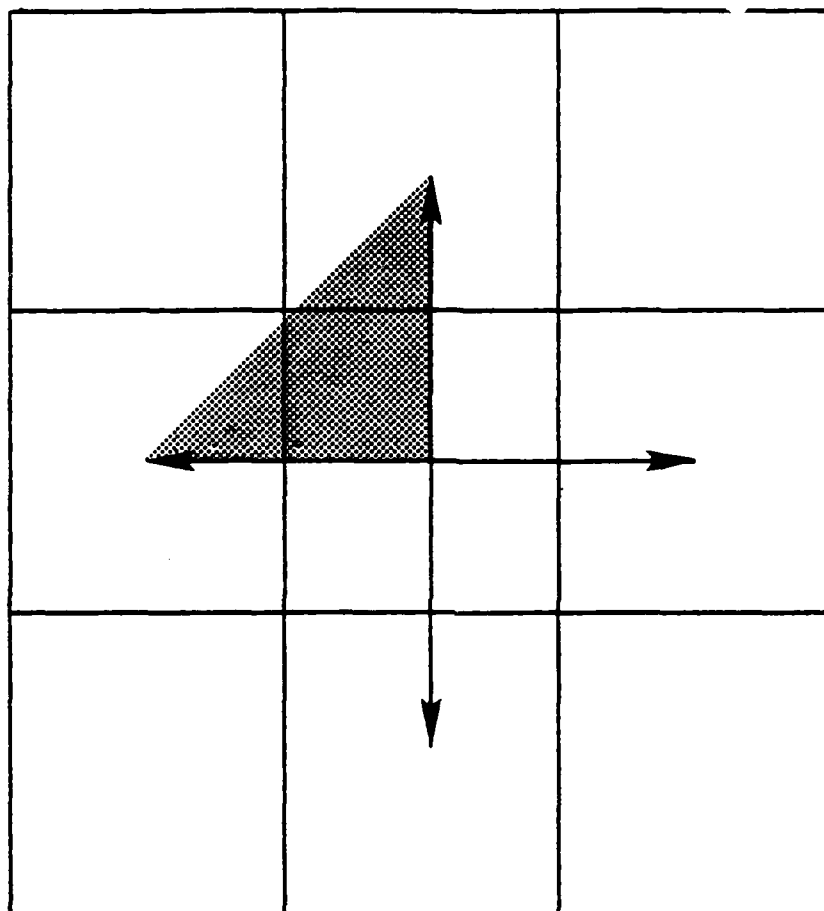


Figure 5-1. Plan View of Grid Cells, Vectors, and a Shaded ITA

$$\begin{aligned}\vec{A} \times \vec{B} &= \begin{vmatrix} \vec{a}_2 & \vec{a}_3 \\ \vec{b}_2 & \vec{b}_3 \end{vmatrix} \vec{i} - \begin{vmatrix} \vec{a}_1 & \vec{a}_3 \\ \vec{b}_1 & \vec{b}_3 \end{vmatrix} \vec{j} + \begin{vmatrix} \vec{a}_1 & \vec{a}_2 \\ \vec{b}_1 & \vec{b}_2 \end{vmatrix} \vec{k} \\ &= |\vec{a}_2 \vec{b}_3 - \vec{a}_3 \vec{b}_2| \vec{i} - |\vec{a}_1 \vec{b}_3 - \vec{a}_3 \vec{b}_1| \vec{j} + |\vec{a}_1 \vec{b}_2 - \vec{a}_2 \vec{b}_1| \vec{k}\end{aligned}$$

where

$$\vec{B} = \langle \vec{b}_1 \vec{i} + \vec{b}_2 \vec{j} + \vec{b}_3 \vec{k} \rangle$$

$$\vec{A} = \langle \vec{a}_1 \vec{i} + \vec{a}_2 \vec{j} + \vec{a}_3 \vec{k} \rangle$$

ITA local origin = (0, 0, 0)

The choice of origins allows the above expression to be simplified because \vec{A} does not have an eastern component $\vec{a}_1=0$ and \vec{B} does not have a northern component $\vec{b}_2=0$. The cross product then reduces to:

$$\vec{A} \times \vec{B} = \vec{a}_2 \vec{b}_3 \vec{i} + \vec{a}_3 \vec{b}_1 \vec{j} - \vec{a}_2 \vec{b}_1 \vec{k}$$

A horizontal ITA will have $\vec{a}_3=\vec{b}_3=0$ (no displacement in Z) and the normal vector will be along the Z axis. For a regularly spaced X-Y grid $\vec{a}_1=\vec{b}_2=0$ and $\vec{a}_2 \vec{b}_1$ is a constant provided small areas in latitude are considered. If the input grid covers large north-south distances $\vec{a}_2 \vec{b}_1$ would have to be adjusted by a latitude correction factor.

The cross sectional area depends on the orientation of the ITA and the bearing of the source. The cross sectional area is azimuth dependent and therefore dependent on the source position. The seamount target strength will vary depending on the direction from which it is insonified.

A perspective view of an ITA is shown in Figure 5-2 with the source raypath \vec{P} and the ITA normal vector \vec{N} . As the raypath \vec{P} and the ITA normal vector \vec{N} become more parallel, a larger area is exposed to the wave front. This larger exposed area scatters more energy which is indicated by an increase in the target strength.

The area used to compute target strength is determined by finding the component of \vec{N} along \vec{P} . This is analogous to finding the cross sectional area of an ITA as "seen" by a horizontally traveling wave front.

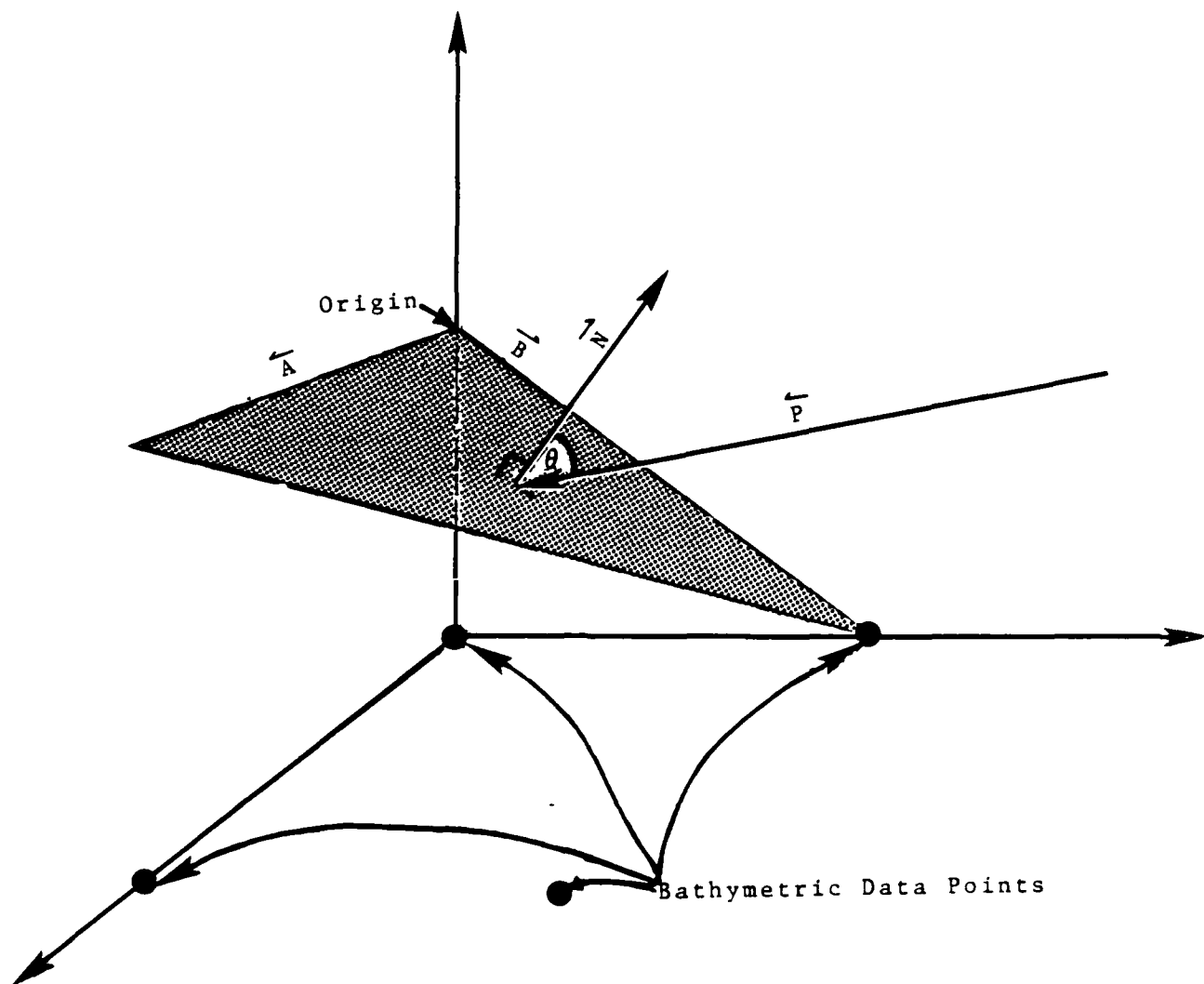
The component of \vec{N} in the direction of \vec{P} is determined by

$$\vec{N} \text{ comp } \vec{P} = (\vec{N} \cdot \vec{P} / |\vec{P}|) / 2.$$

This is the area of the orthogonal projection of the ITA determined by \vec{A} and \vec{B} onto the plane wave whose normal unit vector is $\vec{P}/|\vec{P}|$.

In summary, target strength estimates for seamounts are determined from digital bathymetric grids. Groups of grid cells within a seamount are determined by a contouring algorithm. The vertical cross sectional area of each cell within the seamount is determined by evaluating the four nearest grid cell neighbors. Vector techniques are used to determine the vertical cross sectional area which is assumed to be proportional to target strength. The seamount target strength is azimuth dependent because the cross sectional area is azimuth dependent.

The target strength calculation does not consider the pulse time spread introduced by the fact that the seamount flanks are extended in range. Factors affecting the time spread include the radius dimension, flank slopes, range and time duration of the pulse.



\vec{N} : Normal vector to the ITA

\vec{P} : Raypath vector

\vec{A} : North-South vector

\vec{B} : East-West vector

Figure 5-2. Perspective View of ITA and Positional Vectors

The response of a seamount of radius R , total target strength TS , and insonified by a pulse of duration T , can be approximated by the following equations:

For a long pulse, such that $T \gg 2R/c$,

$$\text{Echo Level} = SL - TL1 + TS - TL2$$

where $TL1$ and $TL2$ are the transmission losses along the two paths from source and receiver to the seamount. The time duration of the echo is on the order of the pulse length T .

For a very short pulse, such that $T \ll 2R/c$,

$$\text{Echo Level} = SL - TL1 + TS - TL2 + 10 \log(cT/2R)$$

and the duration of the echo is on the order of $2R/c$, which represents the time for the pulse to travel past the seamount. Details of the response will depend on the shape of the seamount and on the bistatic geometry of source and receiver.

Section 6

SEAMOUNT DATA BASE COMPARISONS

The Bathymetric Analysis Software (BAS) reads a rectangular grid of bathymetric data and delineates seamounts within the grid. A data base containing location, shape and target strength statistics results. To evaluate the integrity of the digital seamount data base a manual data base of seamount statistics was created. Both data bases were compiled from the NOP test area which covers approximately 50,000 square nautical miles.

Statistics for the manually generated data base were derived by measuring seamount positions and shapes from the Bottom Topography of the North Atlantic Ocean (NOO SP-1304). This is a confidential atlas containing the bathymetry of the North Atlantic. Statistics for the digital data base were created from a one sixth degree bathymetric data base (DBDB6).

Manual seamount selection was based upon the seamount base area and maximum height above the mean sea floor. The largest seamounts within the test area were selected with a minimum height of 500 meters. The manual seamount data base was compiled before the development of the seamount extraction software. Descriptions of the manual statistics derived from the atlas follow along with a table of the selected seamounts.

- Lat-Long: The approximate center point of the seamount.

- Height: The height is calculated in meters above the local mean sea floor elevation. The mean value of the sea floor is considered to be the slowly varying elevations just off of the flanks of the seamount.
- Major Axis: Distance in nautical miles of the longest chord that can be drawn through the plan view of the seamount.
- Minor Axis: Distance in nautical miles of the chord perpendicular to the major axis that can be drawn through the seamount.
- Base Area: Estimated by summing the area within the lowest contour that enclosed the seamount. The lowest contour is typically one level above the mean sea floor elevation.

6.1 MANUAL SEAMOUNT STATISTICS

The following statistics were derived by manually measuring the largest seamounts in the NOP Test Area. The major and minor axis information was gathered as a seamount base shape indicator.

SEAMOUNT NAME	LAT LONG	HEIGHT METERS	MAJOR AXIS NM	MINOR AXIS NM	BASE AREA NM
BALANUS	39.38 66.55	3122	16	16	324
KELVIN	38.83 64.00	3225	32	16	576
GOSNOLD	38.16 62.33	3394	32	11	516

SEAMOUNT NAME	LAT LONG	HEIGHT METERS	MAJOR AXIS NM	MINOR AXIS NM	BASE AREA NM
GREGG	38.90 61.00	3394	25	12	420
MANNING SEAMOUNTS	38.1 61.0	3300	25	11	342
BERMUDA	32.4 64.7	3000	30	24	672
UNNAMED	38.35 60.48	2700	18	14	270
UNNAMED	38.33 60.75	2100	11.5	7	78
SAN PABLO	38.9 60.33	3300	18	11.5	228
VOGEL	37.2 60.2	2200	23	9	246
CARYN	36.75 67.9	2000	9.2	9.2	108
KIWI	39.33 65.66	900	8	8	54
PICKET	39.66 65.9	2000	17	11.5	192
RETRIEVER	39.83 66.25	1900	11.5	9.2	102
PHYSALIA	39.85 66.9	1500	9.2	5.8	60
BEAR	39.9 67.45	900	9.2	7	66
MYTILUS	39.4 67.16	1600	14	7	120
ASTERIAS	38.9 65.3	1400	7	7	54

SEAMOUNT NAME	LAT LONG	HEIGHT METERS	MAJOR AXIS NM	MINOR AXIS NM	BASE AREA NM
PANULIRUS	38.5 64.8	900	4.6	4.6	18
SHELDRAKE	38.41 62.16	2600	14	14	168
UNNAMED	38.5 63.16	2000	18.4	11.5	276
UNNAMED	38.25 63.0	1000	9.2	7	60
UNNAMED	35.66 64.1	1000	18.2	7	150
UNNAMED	39.1 66.35	1400	12	10	68
UNNAMED	35.4 63.6	600	24	7.5	170
UNNAMED	35 62.8	1400	15	10	96
UNNAMED	36.6 60.8	650	12	7	50
UNNAMED	35.2 63.1	500	19	19	168
UNNAMED	39.6 60.9	700	11	7	73
UNNAMED	39.6 60.7	600	7	7	50
UNNAMED	35.9 63.5	500	14	6	60

SEAMOUNT NAME	LAT LONG	HEIGHT METERS	MAJOR AXIS NM	MINOR AXIS NM	BASE AREA NM
MUIR	33.6 62.6	2800	34.5	9.2	378
SIBONEY	33.4 61.60	2700	18.4	11.5	240
GEORGE	33.4 60.8	1700	14	8	84
BOWDITCH	32.8 64.6	1500	9.2	9.2	108
CHALLENGER BANK	32.4 64.8	3800	51	28	1200
BERMUDA	32.4 64.7	3000	30	24	672
UNNAMED	33.7 66.7	1200	5.7	5.5	42
UNNAMED	33.2 65.6	2000	15	7	65
UNNAMED	29.6 65.3	900	30	7	170
UNNAMED	33.5 60.3	800	16	10	165
UNNAMED	34.3 60.1	800	12	8	84

6.2 DIGITAL SEAMOUNT STATISTICS

The delineation of the seamounts was performed by processing a one sixth degree bathymetric grid. The following processing sequences were required:

- 1) Filter bathymetric data with a 5 cell square median filter
- 2) Subtract input grid from filtered output
- 3) Eliminate grid values less than 400 meters (Elevation Threshold)
- 4) Determine the closed elevation highs (Seamounts)
- 5) Calculate position statistics, shape, heights and target strength
- 6) Write statistics out to a file.

Additional statistics derived from the digital bathymetric data include:

- X-Section Area: The seamount area as projected into a vertical plane along the source bearing. An eastward source bearing was used to compute the listing below.
- Radius: The radius of a circle that has an equivalent area as the seamount base area.
- Target Strength: Calculated by the equation

$$TS = 10 \log (X\text{-Section AREA}) + 10 \log (\beta/90)$$

where X-Section AREA is in meters and β is constant at 15 degrees.

Digital Seamount Data Base

LAT DEG	LONG DEG	MAX HEIGHT METERS	BASE AREA NM	RADIUS NM	X-SECTION AREA NM	TARGET STRENGTH dB
31.08	-63.73	525	78.	5.0	3.0	62.3
32.42	-64.81	2819	1787.	23.8	137.1	78.9
33.17	-65.64	1439	233.	8.6	14.1	69.1
33.33	-60.81	1083	311.	9.9	9.3	67.3
33.42	-61.56	2316	233.	8.6	23.5	71.3
33.50	-62.31	1964	233.	8.6	16.2	69.7
33.83	-62.48	1930	233.	8.6	20.4	70.7
34.08	-62.73	842	78.	5.0	6.3	65.6
34.25	-60.06	611	78.	5.0	2.7	61.9
34.25	-62.23	432	78.	5.0	2.0	60.6
35.08	-62.73	467	78.	5.0	2.0	60.7
35.25	-63.39	488	78.	5.0	2.2	60.9
35.42	-63.73	480	78.	5.0	3.0	62.3
35.75	-64.06	461	78.	5.0	2.1	60.8
36.58	-60.73	510	78.	5.0	3.1	62.4
36.67	-67.89	1038	155.	7.0	8.1	66.7
36.75	-59.73	559	78.	5.0	4.6	64.2
37.17	-60.14	1285	311.	9.9	18.0	70.1
37.33	-59.98	1974	155.	7.0	18.8	70.3
37.58	-59.81	3226	311.	9.9	24.8	71.5
38.00	-62.14	2072	233.	8.6	5.4	64.9
38.17	-60.56	2545	1165.	19.3	71.8	76.1
38.25	-62.48	2384	466.	12.2	31.1	72.5
38.42	-62.06	2001	78.	5.0	7.4	66.3
38.42	-63.06	2656	777.	15.7	53.2	74.8
38.83	-60.39	2399	388.	11.1	16.5	69.8
38.83	-63.81	2845	621.	14.1	37.2	73.3
38.92	-60.81	2547	699.	14.9	42.4	73.8
38.92	-65.23	461	78.	5.0	2.6	61.7
39.08	-66.39	856	78.	5.0	4.4	64.0
39.33	-65.31	2126	311.	9.9	15.4	69.4
39.42	-67.14	1232	155.	7.0	9.0	67.1
39.67	-65.89	1352	155.	7.0	9.4	67.3
39.92	-66.23	1052	78.	5.0	5.4	64.9
39.92	-67.31	1117	155.	7.0	5.8	65.2
40.42	-66.98	523	155.	7.0	0.0	0.0
41.25	-65.89	439	78.	5.0	0.0	0.0

Seamounts that have zero X-Section area have been assigned a target strength of zero. The X-Section area depends on the orientation of the seamount. The smaller seamounts (1 or 2 grid cells) often show zero X-Section area because they are orientated parallel to the source ray path.

The seamount locations were plotted for both the manual (Figure 6-1) and the digital database (Figure 6-2). The seamount concentrations and trends are quite similar although there are location discrepancies. These discrepancies may be explained due to the differences in the data used to derive the location information.

The manual and digital seamount data bases are not in perfect agreement. The resolution of the input bathymetric data probably had the greatest affect on the location discrepancy. Listed below are some of the factors that explain the location discrepancies.

Manual Data Base

- 1) Higher resolution data
- 2) Analog display
- 3) Areas calculated along smooth contours
- 4) Subjective selection of seamounts

Digital Data Base

- 1) Lower resolution data
- 2) Objective seamount selection
- 3) Areas calculated as multiples of a grid cell

Mercator Projection

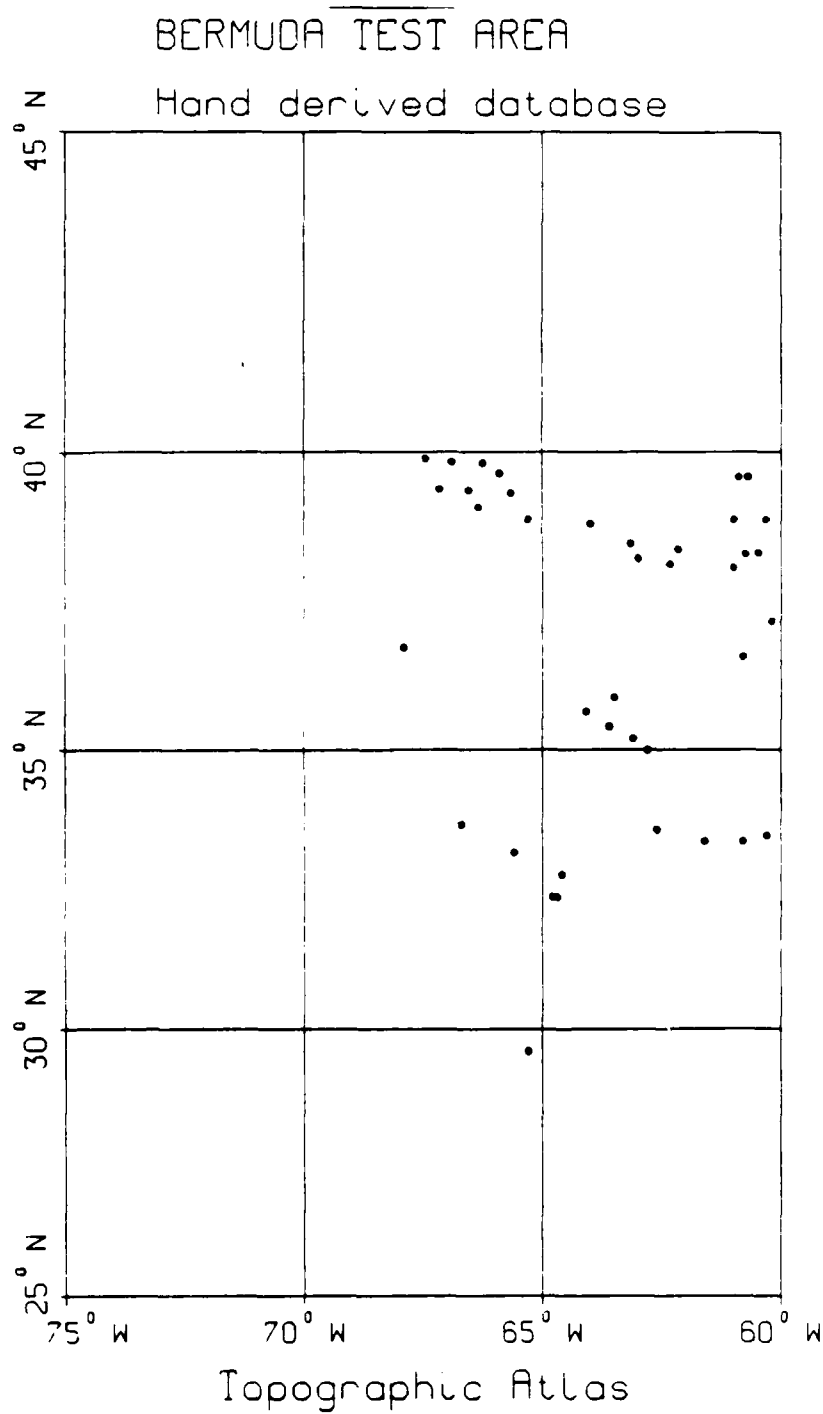


Figure 6-1. Seamount Locations Derived Manually

Mercator Projection

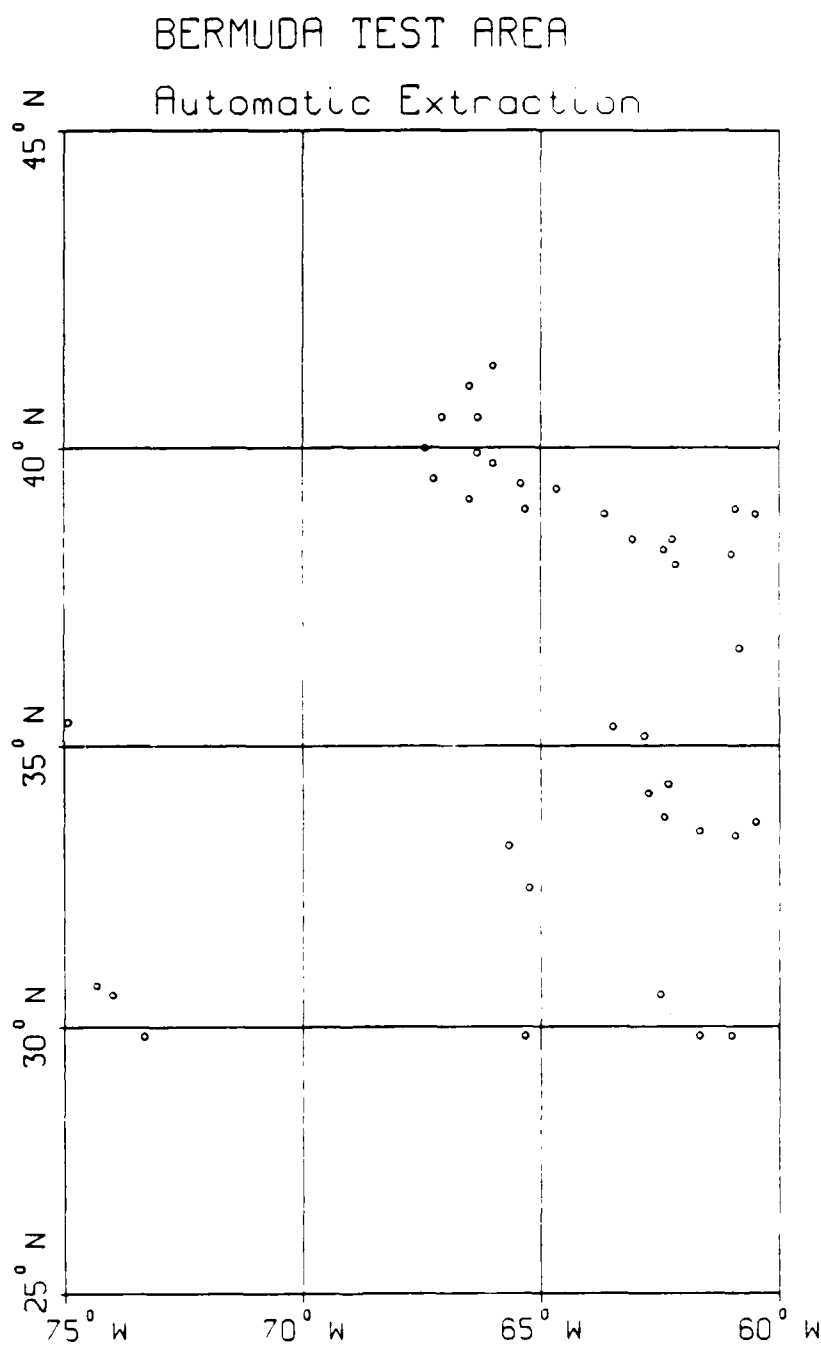


Figure 6-2. Seamount Locations Derived Automatically

The BAS has an option that will allow the user to perform track analysis on the seamount data base. The following inputs are required to define a track:

- 1) Seamount data base name
- 2) Source position Lat-Long
- 3) Bearing
- 4) Beam width
- 5) Maximum range

The data base is searched and statistics for all seamounts that have center points within the beam width are retrieved.

Appendix A

REFERENCES RELATING TO THE SEAMOUNT STUDY

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Appendix B
LISTING OF SEAMOUNTS FROM NSWC

KELVIN SEAMOUNT EAST

Average Latitude/Longitude	:	38.87	63.79
Average slope angle (in degrees)	:	9.8	
Segment Lengths (in nautical miles)	:		
		1	2.5
		2	2.0
		3	1.1
Segment Vertical Areas (in square nmiles)	:		
		1	2.7
		2	2.4
		3	1.9
Target Strength (dB//yd)	:		
		1	60.6
		2	60.2
		3	59.3

KELVIN SEAMOUNT WEST

Average Latitude/Longitude	:	38.82	64.06
Average slope angle (in degrees)	:	9.3	
Segment Lengths (in nautical miles)	:		
		1	5.6
		2	7.1
		3	11.3
Segment Vertical Areas (in square nmiles)	:		
		1	4.7
		2	5.6
		3	8.1
Target Strength (dB//yd)	:		
		1	62.9
		2	63.7
		3	65.3

NESMT1

Average Latitude/Longitude	:	38.51	63.22
Average slope angle (in degrees)	:	7.9	
Segment Lengths (in nautical miles)	:		
		1	6.0
		2	2.6
		3	8.4
		4	3.3
Segment Vertical Areas (in square nmiles)	:		
		1	5.2
		2	3.2
		3	6.7
		4	3.6
Target Strength (dB//yd)	:		
		1	62.6
		2	60.5
		3	63.7
		4	61.0

NESMT2

Average Latitude/Longitude	:	38.31	63.00
Average slope angle (in degrees)	:	11.0	
Segment Lengths (in nautical miles)	:		
		1	4.5
		2	3.1
		3	2.1
		4	4.7
Segment Vertical Areas (in square nmiles)	:		
		1	7.1
		2	5.6
		3	4.5
		4	7.3
Target Strength (dB//yd)	:		
		1	65.4
		2	64.3
		3	63.4
		4	65.5

NESMT3

Average Latitude/Longitude : 38.40 62.81

Average slope angle (in degrees) : 13.9

Segment Lengths (in nautical miles) :

1	3.8
2	1.6
3	4.6

Segment Vertical Areas (in square nmiles) :

1	5.8
2	3.6
3	6.7

Target Strength (dB//yd) :

1	65.5
2	63.4
3	66.1

SHELDRAKE SEAMOUNT

Average Latitude/Longitude : 38.22 62.48

Average slope angle (in degrees) : 23.4

Segment Lengths (in nautical miles) :

1	3.1
2	8.1
3	1.5
4	11.2

Segment Vertical Areas (in square nmiles) :

1	2.4
2	5.4
3	1.5
4	7.2

Target Strength (dB//yd) :

1	63.9
2	67.4
3	61.8
4	68.7

NR SHELDARKE SEAMOUNT

Average Latitude/Longitude : 38.03 62.20

Average slope angle (in degrees) : 13.9

Segment Lengths (in nautical miles) :

1	2.8
2	3.0
3	5.4

Segment Vertical Areas (in square nmiles) :

1	2.8
2	2.9
3	4.5

Target Strength (dB//yd) :

1	62.3
2	62.5
3	64.4

MANNING SEAMOUNT WEST

Average Latitude/Longitude : 38.08 61.00

Average slope angle (in degrees) : 12.7

Segment Lengths (in nautical miles) :

1	5.3
2	3.7
3	6.6
4	1.9

Segment Vertical Areas (in square nmiles) :

1	4.2
2	3.2
3	4.9
4	2.2

Target Strength (dB//yd) :

1	63.7
2	62.6
3	64.5
4	60.9

MANNING SEAMOUNT EAST

Average Latitude/Longitude : 38.23 60.48

Average slope angle (in degrees) : 11.4

Segment Lengths (in nautical miles) :

1	7.2
2	2.3
3	6.2
4	1.5

Segment Vertical Areas (in square nmiles) :

1	5.4
2	2.5
3	4.8
4	2.0

Target Strength (dB//yd) :

1	64.4
2	61.1
3	63.9
4	60.1

MANNING SEAMOUNT SOUTH

Average Latitude/Longitude : 38.06 60.82

Average slope angle (in degrees) : 13.9

Segment Lengths (in nautical miles) :

1	2.2
2	3.3
3	1.7

Segment Vertical Areas (in square nmiles) :

1	2.2
2	2.9
3	1.9

Target Strength (dB//yd) :

1	61.4
2	62.5
3	60.7

SAN PABLO SEAMOUNT WEST

Average Latitude/Longitude : 38.97 61.03

Average slope angle (in degrees) : 13.4

Segment Lengths (in nautical miles) :

1	2.3
2	8.7
3	10.4

Segment Vertical Areas (in square nmiles) :

1	2.5
2	6.9
3	8.1

Target Strength (dB//yd) :

1	61.7
2	66.1
3	66.8

SAN PABLO SEAMOUNT EAST

Average Latitude/Longitude : 38.86 60.39

Average slope angle (in degrees) : 12.7

Segment Lengths (in nautical miles) :

1	2.3
2	4.0
3	1.1
4	6.0

Segment Vertical Areas (in square nmiles) :

1	2.5
2	3.7
3	1.6
4	5.0

Target Strength (dB//yd) :

1	61.5
2	63.2
3	59.7
4	64.5

BALANUS SEAMOUNT

Average Latitude/Longitude : 39.40 65.41

Average slope angle (in degrees) : 13.6

Segment Lengths (in nautical miles) :

1	2.9
2	2.5
3	3.0
4	2.9
5	4.8

Segment Vertical Areas (in square nmiles) :

1	2.8
2	2.6
3	2.9
4	2.8
5	4.2

Target Strength (dB//yd) :

1	62.3
2	61.9
3	62.5
4	62.3
5	64.0

BEAR SEAMOUNT

Average Latitude/Longitude : 39.92 67.43

Average slope angle (in degrees) : 4.7

Segment Lengths (in nautical miles) :

1	4.5
2	4.6
3	7.0
4	5.5

Segment Vertical Areas (in square nmiles) :

1	5.4
2	5.5
3	7.4
4	6.2

Target Strength (dB//yd) :

1	60.5
2	60.6
3	61.9
4	61.1

MUIR SEAMOUNT NORTH

Average Latitude/Longitude : 33.87 62.62

Average slope angle (in degrees) : 26.3

Segment Lengths (in nautical miles) :

1	4.1
2	4.0
3	2.6

Segment Vertical Areas (in square nmiles) :

1	3.9
2	3.9
3	2.5

Target Strength (dB//yd) :

1	66.6
2	66.5
3	64.7

MUIR SEAMOUNT SOUTH

Average Latitude/Longitude : 33.60 62.45

Average slope angle (in degrees) : 26.3

Segment Lengths (in nautical miles) :

1	17.2
2	3.5
3	14.3

Segment Vertical Areas (in square nmiles) :

1	10.2
2	2.5
3	8.5

Target Strength (dB//yd) :

1	70.7
2	64.6
3	69.9

BERMUDA

Average Latitude/Longitude : 32.25 64.89

Average slope angle (in degrees) : 8.1

Segment Lengths (in nautical miles) :

1	8.7
2	13.2
3	25.9
4	10.4
5	9.7
6	27.6
7	19.9

Segment Vertical Areas (in square nmiles) :

1	7.7
2	14.5
3	33.3
4	10.3
5	9.2
6	35.8
7	24.3

Target Strength (dB//yd) :

1	64.4
2	67.2
3	70.8
4	65.7
5	65.2
6	71.1
7	69.4

BOWDITCH SEAMOUNT

Average Latitude/Longitude : 32.73 64.54

Average slope angle (in degrees) : 10.0

Segment Lengths (in nautical miles) :

1	5.1
2	3.4
3	4.2

Segment Vertical Areas (in square nmiles) :

1	5.0
2	3.6
3	4.2

Target Strength (dB//yd) :

1	63.4
2	61.9
3	62.7

REHOBOTH SEAMOUNT

Average Latitude/Longitude : 37.54 59.81

Average slope angle (in degrees) : 9.3

Segment Lengths (in nautical miles) :

1	4.4
2	5.0
3	5.0

Segment Vertical Areas (in square nmiles) :

1	3.7
2	3.9
3	3.9

Target Strength (dB//yd) :

1	61.8
2	62.1
3	62.1

SOUTH OF REHOBOTH SEAMOUNT

Average Latitude/Longitude : 36.92 58.92

Average slope angle (in degrees) : 9.3

Segment Lengths (in nautical miles) :

1	12.8
2	6.4
3	6.4

Segment Vertical Areas (in square nmiles) :

1	7.8
2	4.6
3	4.6

Target Strength (dB//yd) :

1	65.1
2	62.8
3	62.8

NE OF MUIR SEAMOUNT (N)

Average Latitude/Longitude : 35.33 58.06

Average slope angle (in degrees) : 9.3

Segment Lengths (in nautical miles) :

1	17.1
2	17.1
3	10.0

Segment Vertical Areas (in square nmiles) :

1	9.9
2	9.9
3	6.4

Target Strength (dB//yd) :

1	66.1
2	66.1
3	64.2

NE OF MUIR(S) (1500)

Average Latitude/Longitude : 34.61 56.85

Average slope angle (in degrees) : 20.3

Segment Lengths (in nautical miles) :

1	17.8
2	9.8
3	5.0
4	5.1
5	6.3
6	27.6

Segment Vertical Areas (in square nmiles) :

1	14.7
2	8.7
3	5.2
4	5.2
5	6.1
6	21.9

Target Strength (dB//yd) :

1	71.2
2	69.0
3	66.7
4	66.7
5	67.4
6	72.9

PHYSALIA SEAMOUNT

Average Latitude/Longitude : 39.86 66.97

Average slope angle (in degrees) : 10.9

Segment Lengths (in nautical miles) :

1	4.6
2	5.6
3	6.9

Segment Vertical Areas (in square nmiles) :

1	7.3
2	8.4
3	9.9

Target Strength (dB//yd) :

1	65.5
2	66.1
3	66.8

RETRIEVER SEAMOUNT

Average Latitude/Longitude : 39.85 66.28

Average slope angle (in degrees) : 8.8

Segment Lengths (in nautical miles) :

1	2.0
2	5.9
3	3.3
4	5.2
5	6.5

Segment Vertical Areas (in square nmiles) :

1	4.9
2	9.3
3	6.3
4	8.4
5	9.9

Target Strength (dB//yd) :

1	62.7
2	65.6
3	63.9
4	65.1
5	65.8

PICKETT SEAMOUNT

Average Latitude/Longitude : 39.66 65.97

Average slope angle (in degrees) : 9.8

Segment Lengths (in nautical miles) :

1 2.4
2 4.1
3 4.6
4 3.8

Segment Vertical Areas (in square nmiles) :

1 5.0
2 7.0
3 7.5
4 6.6

Target Strength (dB//yd) :

1 63.4
2 64.8
3 65.1
4 64.5

SW OF BALANUS

Average Latitude/Longitude : 39.09 66.39

Average slope angle (in degrees) : 11.2

Segment Lengths (in nautical miles) :

1 2.5
2 1.0
3 3.1
4 0.6

Segment Vertical Areas (in square nmiles) :

1 4.6
2 3.5
3 5.0
4 3.2

Target Strength (dB//yd) :

1 63.6
2 62.4
3 64.0
4 62.0

MYTILUS SEAMOUNT

Average Latitude/Longitude : 39.39 67.21

Average slope angle (in degrees) : 8.2

Segment Lengths (in nautical miles) :

1	1.9
2	1.8
3	3.0
4	1.8
5	3.7

Segment Vertical Areas (in square nmiles) :

1	5.3
2	5.3
3	6.2
4	5.3
5	6.8

Target Strength (dB//yd) :

1	62.9
2	62.8
3	63.6
4	62.8
5	63.9

SIBONEY SEAMOUNT

Average Latitude/Longitude : 33.43 61.60

Average slope angle (in degrees) : 9.6

Segment Lengths (in nautical miles) :

1	5.0
2	1.7
3	4.9
4	4.3

Segment Vertical Areas (in square nmiles) :

1	8.0
2	4.1
3	7.8
4	7.2

Target Strength (dB//yd) :

1	65.3
2	62.4
3	65.2
4	64.8

GEORGE SEAMOUNT

Average Latitude/Longitude : 33.39 60.83

Average slope angle (in degrees) : 10.0

Segment Lengths (in nautical miles) :

1	7.1
2	2.7
3	6.5

Segment Vertical Areas (in square nmiles) :

1	9.5
2	5.4
3	8.9

Target Strength (dB//yd) :

1	66.2
2	63.8
3	66.0

NW OF BERMUDA

Average Latitude/Longitude : 33.17 65.59

Average slope angle (in degrees) : 13.9

Segment Lengths (in nautical miles) :

1	2.9
2	2.8
3	3.4

Segment Vertical Areas (in square nmiles) :

1	4.8
2	4.7
3	5.2

Target Strength (dB//yd) :

1	64.7
2	64.6
3	65.0

VOGEL SEAMOUNT

Average Latitude/Longitude : 37.12 60.17

Average slope angle (in degrees) : 7.6

Segment Lengths (in nautical miles) :

1	1.3
2	1.6
3	2.5

Segment Vertical Areas (in square nmiles) :

1	4.8
2	5.1
3	6.1

Target Strength (dB//yd) :

1	62.1
2	62.3
3	63.1

ASTERIAS SEAMOUNT

Average Latitude/Longitude : 38.91 65.30

Average slope angle (in degrees) : 11.2

Segment Lengths (in nautical miles) :

1	2.1
2	2.2
3	2.0

Segment Vertical Areas (in square nmiles) :

1	6.5
2	6.5
3	6.4

Target Strength (dB//yd) :

1	65.0
2	65.1
3	65.0

CARYN SEAMOUNT

Average Latitude/Longitude : 38.78 67.91

Average slope angle (in degrees) : 8.6

Segment Lengths (in nautical miles) :

1	2.6
2	4.0
3	1.9

Segment Vertical Areas (in square nmiles) :

1	7.5
2	8.8
3	6.9

Target Strength (dB//yd) :

1	64.6
2	65.2
3	64.2

E OF BLAKESPUR

Average Latitude/Longitude : 30.70 74.42

Average slope angle (in degrees) : 0.3

Segment Lengths (in nautical miles) :

1	9.9
2	9.8
3	10.4

Segment Vertical Areas (in square nmiles) :

1	138.0
2	137.9
3	138.4

Target Strength (dB//yd) :

1	63.3
2	63.3
3	63.3

705 E CENTRAL(1800)

Average Latitude/Longitude : 27.00 65.79

Average slope angle (in degrees) : 7.0

Segment Lengths (in nautical miles) :

1	3.7
2	3.0
3	2.4
4	3.3

Segment Vertical Areas (in square nmiles) :

1	10.0
2	9.3
3	8.7
4	9.6

Target Strength (dB//yd) :

1	64.9
2	64.6
3	64.3
4	64.7

705 W CENTRAL(1800)

Average Latitude/Longitude : 27.46 66.65

Average slope angle (in degrees) : 13.9

Segment Lengths (in nautical miles) :

1	1.0
2	0.7
3	1.1

Segment Vertical Areas (in square nmiles) :

1	4.2
2	3.8
3	4.2

Target Strength (dB//yd) :

1	64.1
2	63.7
3	64.1

HODGES SEAMOUNT(1500)		
Average Latitude/Longitude	:	31.88 58.70
Average slope angle (in degrees)	:	13.9
Segment Lengths (in nautical miles)	:	
	1	6.1
	2	3.7
	3	6.9
Segment Vertical Areas (in square nmiles)	:	
	1	6.7
	2	5.0
	3	7.3
Target Strength (dB//yd)	:	
	1	66.1
	2	64.8
	3	66.5

WYOMING SEAMOUNT(1500)		
Average Latitude/Longitude	:	33.46 56.92
Average slope angle (in degrees)	:	12.1
Segment Lengths (in nautical miles)	:	
	1	3.1
	2	3.8
	3	3.0
	4	3.5
Segment Vertical Areas (in square nmiles)	:	
	1	4.8
	2	5.4
	3	4.8
	4	5.2
Target Strength (dB//yd)	:	
	1	64.1
	2	64.6
	3	64.0
	4	64.4

CONGRESS SEAMOUNT(1800)	:	33.14	54.80
Average Latitude/Longitude	:	18.2	
Average slope angle (in degrees)	:		
Segment Lengths (in nautical miles)	:		
		1	2.0
		2	2.4
		3	1.1
Segment Vertical Areas (in square nautical miles) :			
		1	4.1
		2	4.5
		3	3.4
Target Strength (dB//yd)	:		
		1	65.2
		2	65.6
		3	64.3

END

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